The adaptive reuse of inner-city car parking structures for innovative controlled environment agriculture systems.

An architectural and urban investigation into the potential for the sustainable regeneration of modern derived infrastructures in some contemporary UK cities.

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Synopsis

The global food supply can trigger adverse impacts, which are evident in the UK context. Developing a local food system is required, however this is a challenge due to its complexity. In the urban context, buildings are seen as a resource that when up-cycled can provide a space for controlled environment agriculture as the most productive urban farming technique. This thesis investigates the architectural typology of modern movement multi-storey garages, whose future is now discussed due to their function, aesthetics and inner-city location, offering new insights into one of the alternatives in which they can be put to use.

The research aims to explore the adaptive reuse potential of inner-city modern movement car parking structures for a viable controlled environment agriculture operation from the architect`s perspective, and to determine the alterations within the existing architectural typology that would be required to accommodate this innovative use as a response to changing urban demands. The investigation, led by the design thinking process, is divided into research for design and research by design. Research for design theoretically explores the planning, architectural and environmental criteria relevant from the architect`s perspective for the proposed up-cycling in the temperate climatic zone. Based on these findings, a guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for controlled environment agriculture has been developed and applied to the case studies in the UK as explanatory research by design, which has led to the development of initial design scenarios. As a result, the up-cycling potential of three garages has been conceptualised in planning, architectural and environmental categories, providing insights on the type-alterations required to accommodate this innovative use in the urban environment.

The conclusions indicate that the application of the guide delivers a series of possible avenues which, when based on existing knowledge, offer viable initial design scenarios. The investigation is context-specific because it defines the conditions for long-term functioning, which depend on the fusion between current knowledge and the unique planning, architectural and environmental context of the modern movement garage. Adaptive reuse within this architectural typology may lead to the innovative type-alteration, which allows a building rooted in the past to meet urban demands. It is an adequate decision to determine these alterations at the initial stage of the research due to the flexibility in shaping final design scenarios. However, the key drivers to enable such a retrofit arise from the planning and environmental phases of the guide’s application because they deliver benefits for urban sustainability, which outbalance local food cultivation from the perspective of stakeholders.

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Author’s declaration

Whilst registered as a candidate for the above degree, I have not been registered for any other research award. The results and conclusions embodied in this thesis are the work of the named candidate and have not been submitted for any other academic award.

This study was funded by the University of Portsmouth. A programme of advanced study was undertaken, which included postgraduate training in knowledge and intellectual abilities, personal effectiveness, research governance and organisation as well as engagement, influence and impact of the research. Relevant academic conferences and meetings were regularly attended, with work presented at some of these, one published paper and several papers are being prepared for publication.

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Signed Monika Szopińska-Mularz Dated 16 June 2020

Abbreviations

BIA: Building-integrated Agriculture

BIPV: Building-integrated Photovoltaics

CEA: Controlled Environment Agriculture

CO_2: Carbon Dioxide

CPPS: Closed Plant Production System

DEFRA: Department for Environment, Food and Rural Affairs

FAO: Food and Agriculture Organization of the United Nations

FF: Façade Farm

GIPV: Greenhouse-integrated Photovoltaics

HVAC system: Heating, Ventilation, and Air Conditioning system

i-RTG: Integrated Rooftop greenhouse

LCA: Life Cycle Assessment

LED: Light-emitting diode

NGO: Non-governmental organization

NTF: Nutrient film technique

OECD: The Organisation for Economic Co-operation and Development

PC: Polycarbonate

PFAL: Plant Factory with Artificial Lighting

PFSL: Plant Factory with Sun Light

PMMA: Polymethacrylate

PV: Photovoltaic panels

RTG: Rooftop Greenhouse

TOD: Transit-oriented development

UA: Urban agriculture

UF: Urban farming

UK: United Kingdom

UNICEF: The United Nations Children's Fund

VF: Vertical farming

VIG: Vertically-integrated greenhouse

ZFarming: Zero-acreage farming

Key words

Adaptive reuse of modern movement car parking structures, controlled environment agriculture, urban agriculture, building-integrated agriculture, research for design, research by design

Dedication

To my husband Bartek,

for your support and help with keeping a life-work balance, especially when travelling.

To my parents Grazyna and Lech,

for their constant belief in me, encouragement and support.

To my children Tymon and Weronika,

for reminding me that my most important role is to be a mum, and proving that PhD research is easy when compared to bringing up two little kids.

Dissemination

This research has been presented at the CCI Postgraduate Research Conference at the University of Portsmouth on the 14th of June 2017 and the 15th International DOCOMOMO Conference: Metamorphosis. The Continuity of Change in Ljubljana, Slovenia on the 30th of August 2018.

Two papers have been published:

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The two papers have been written and are awaiting publication:

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Chapter 1: Introduction

1.1. Scope and study area

This thesis argues for the significance of analysing the adaptive reuse potential of inner-city modern movement car parking structures for controlled environment agriculture (CEA) from the architect`s perspective, for developing viable initial design scenarios for food cultivation as a secondary food source in urban areas. From the typological perspective, this research explores the potential of the modern movement architectural type to become the stimulating force behind a design process (Rossi, 1982) that is required due to the urban evolution which is allowing that type to gain significance regardless of its original function.

To explore such potential, the investigation, guided by the design thinking process, can be divided into research for design, and research by design. Research for design is a theoretical investigation of secondary and primary sources. The secondary exploration consists of a literature review on the planning, architectural and environmental aspects of building-based CEA located in the temperate climatic zone, which is relevant to inform the architect at the initial stage of the up-cycling scenario development. This analysis is validated and deepened by the exploratory case study research consisting of three CEA urban operations. Semi-structured interviews with experts are the foundation for the primary investigation, narrowed down to inner-city modern movement garages in the UK context, which led to the conceptualisation of planning, architectural and environmental criteria that should be met in order to develop viable initial up-cycling proposals. To achieve that goal, the limitations and opportunities concerning each criterion have been formulated as findings from the interviews. Based on the knowledge generated from the research for design phase, the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA has been developed and applied to the strategically selected cases of inner-city car parking structures in the UK. This initiated the explanatory investigation conducted as research by design, which led to the development of the initial design up-cycling proposals. The exploration and critical evaluation of findings was the foundation for determining the alterations to the existing architectural typology that are required for accommodating CEA as a response to changing urban demands.

1.2. Rationale for the research

The world’s population is continuously growing and is projected to exceed 8.5 million by 2030 and 9.7 million by 2050 (United Nations, 2015). There is a trend towards a concentration of the population in urban areas. While in 1950 only 30 percent of people resided in cities, by 2018 already 55 percent of the world's population was urban. This trend is projected to continue towards 68 percent by 2050 (United Nations, 2018). In developed countries, the main driver of the growing urban population is increased wealth, which results in higher purchasing power, followed by higher consumption and growing demand for processed food (Godfray et al., 2010). However the fastest population increase is projected in those regions, where both the prevalence of undernourishment and vulnerability to the impacts of climate change are the highest (FAO, 2016). These factors combined put intense pressure on the global food system, which is expected to need to increase production by 70 to 100 percent by 2050 to meet global demand without any significant food price rises (Godfray et al., 2010; The Royal Society of London, 2009). The FAO (2014) indicates that the additional food required to feed the global population in 2050 has to be cultivated on existing agricultural land. There is limited possibility for expanding the agricultural area, mainly in some parts of South America and Africa. However, making that additional land productive would intensify the already high social, economic and environmental costs of the global food system.

The social and economic challenges faced by the global food system are rooted in the research technology transfer that occurred between 1950 and the late 1960s, when numerous tools were developed to increase agricultural production without considering quality, safety or the variety of crop yield (Mc Carthy et al., 2018). The focus of the agricultural industry on income generation and export enhancement disregarded the importance of sustenance, and the nutritional quality of the food that was produced. Unfair economic competition between agrarian producers from the developing world and farmers from developed countries contributed to the marginalisation of poor and small countries, smallholder farmers, and small and medium-sized enterprises (King et al., 2017; Webb, 2015). The lack of financial viability of small-scale crop cultivation in developing countries led to excessive economic dependence on the global food system (Jenkins, 2018). These inequalities in the global food value chain fragmented national markets and bought about negative social and economic consequences including increasing impoverishment and food insecurity (King et al., 2017; Mc Carthy et al., 2018; Wilkinson, 2015).

The environmental impacts of the global food system impose costs upon the planet, which are not accounted for in the market price of food products (Jenkins, 2018; Pretty, Ball, Lang, & Morison, 2005; Tegtmeier & Duffy, 2004) and increase the environmental burden, which will contribute a the lower standard of living for future generations (Hudson & Donovan, 2014). The methods that were introduced to increase the productivity of the global food system contribute to the degradation of ecosystem services, including the degradation of soil quality, water pollution caused by leakages of pesticides and nutrients, as well as having a negative impact on biodiversity and wildlife (Connor, Loomis, & Cassman, 2011). Long-distance trade increases the reliance on fossil fuels (Paxton, 2012), the production of processed goods, and the generation of waste from packaging food. Agricultural activities give rise to greenhouse gas (GHG) emissions and activate other climate change drivers, for instance aerosols and changes in albedo (Garnett, 2011). At the same time, the increased frequency and intensity of events associated with climate change (e.g. heatwaves, tropical cyclones or rising sea levels) contribute to a reduction in crop and livestock production, thereby endangering global food security (FAO, 2016; Vermeulen, Campbell, & Ingram, 2012).

In the UK, the approach to supporting and improving the food security of the nation is based on five priority areas: *global availability, diversity of supply, food chain resilience, affordability, and safety and confidence* (DEFRA, 2008, p. 28). Although the British Government is continuously working towards improvements in these areas, targets for availability, access and utilisation of food over time have not been reached, and social food-related issues are growing (Loopstra & Lalor, 2017; Wczasek, 2017). The critical problems include the increasing scale of diet-related diseases (Moreira et al., 2015; Statistic Team NHS Digital, 2018), adult and childhood obesity, hunger, food insecurity and malnutrition (Arteaga, Heflin, & Gable, 2016; Garratt, Spencer, & Ogden, 2016; UNICEF Office of Research, 2017). The scale of these issues within the UK was revealed in the report *Building the Future: Children and the Sustainable Development Goals in Rich Countries* (UNICEF Office of Research, 2017), which shows that out of 41 economically developed nations, the UK is the 8th worst performing on one of the global Sustainable Development Goals: *to end hunger, achieve food security and improved nutrition and promote sustainable agriculture* (UNICEF Office of Research, 2017, p. 14). From an environmental perspective, the dependence of the UK on the global food supply has resulted in adverse impacts associated with increasing the total cropland footprint, of which about 67 percent is located abroad. The distances between the UK and the agricultural land which supplies it with food is responsible for generating CO_2 emissions, increasing the reliance on fossil fuels (Cabinet Office, 2008; De Ruiter, Macdiarmid, Matthews, Kastner, & Smith, 2016; DEFRA, 2016; Jenkins, 2018; Office for National Statistics, 2013) and producing waste from the packaging required. However, a significant contribution to environmental pollution has also been identified within the domestic food system. The main issues include heavy goods vehicle food transport within the UK, which added the most to CO_2 emissions and accounted for 29 percent of total CO_2 emissions from the transportation of food in 2010 (DEFRA, 2012). In 2016, food consumption was responsible for generating 25 percent of food waste, while manufacturing produced a further 1.7m tonnes (Parfitt & Parry, 2016). These impacts of the domestic food system must be reduced in order to achieve the sustainable development goals of the country (Garrone, Melacini, Perego, & Sert, 2016; Göbel, Langen, Blumenthal, Teitscheid, & Ritter, 2015; Sheppard & Rahimifard, 2019).

Therefore, a growing number of organisations and researchers have indicated the need to build a vision for an alternative food supply chain in the UK (e.g. Bristol Food Network, 2009; Herman et al., 2010; Jenkins, 2018; Mc Carthy et al., 2018; Pretty et al., 2005; Specht et al., 2013; Sustain, 2017; Waterlander et al., 2018). Developing urban agriculture (UA), also known as urban farming (UF), within cities has the potential to contribute to the enhancement of a local and sustainable food system in the UK as a secondary food source (Brighton & Hove Food Partnership, 2012; Carey, 2011; Jenkins, 2018; Tomkins, 2014).

In the current urban context, where increasing urban density and compactness are seen as key drivers towards sustainable development (Lehmann, 2010b, 2017), the implementation of UF as a traditional soil-based practice is challenged and limited by competing demands for space, high land value (Lovell, 2010), restricted land availability and access in densely built-up areas (Specht et al., 2013) as well as degraded ecosystem services (Aerts, Dewaelheyns, & Achten, 2016). Therefore, much of the current literature highlights the potential of low-space or no-space UA technologies as an alternative for soil-based farming practices (e.g. Ackerman, 2012; Caplow, 2010; Cerón-Palma, Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall, 2012; Despommier, 2011b; Germer et al., 2011; Gould & Caplow, 2012; Jenkins, 2018; Nelkin & Caplow, 2008; Specht et al., 2013; Thomaier et al., 2014; Ting, Lin, & Davidson, 2016). A significant area of interest investigates the adaptive reuse of urban structures for building-based UA operations carried out in a controlled environment using technologically advanced food cultivation methods, for instance hydroponics (Despommier, 2011; Sanyé-Mengual, Cerón-Palma, Oliver-Solà, Montero, & Rieradevall, 2015; Specht et al., 2013). Existing buildings are seen as a resource that when up-cycled can provide a space within dense urban environments for CEA, which is considered the most productive UF technique (Jenkins, 2018).

The specific architectural type which is now becoming obsolete is the modern movement car parking structure. The growing traffic congestion in UK cities resulted in new ideas for developing more sustainable urban transport and for designing accessible mixed-use areas for pedestrians. The emerging concepts of low-carbon mobility and restrictions on private transport mainly focus on inner-city areas, where cars negatively impact both the environment and social life. Several UK cities have decided to reduce vehicular access to the city centre, such as London, Cambridge and Oxford; other cities such as Brighton & Hove are currently examining these ideas for their future (a phenomenon that is happening in numerous European cities, including Copenhagen, Vienna and Rome). In this context, many of the inner-city car parking megastructures built over the last 60 years may become redundant.

This thesis argues firstly that CEA is one of the adaptive reuse options to which inner-city modern movement car parking structures can be put and secondly, that up-cycling these garages for CEA leads to the alteration of the existing architectural typology as a response to changing urban demands. Predicting the future of mobility in UK cities is complex and involves several issues. While the idea of up-cycling multi-storey car parks is a good question to address, this thesis makes the assumption that private vehicle demand in UK city centres will reduce, as the move to electric cars and autonomous vehicles, and the implementation of car-restraint policies are likely to have spatial consequences. While some multi-storey car parks will still be needed, the value of inner-city land in regeneration areas will be too high to justify its use for parking. The demolition of these structures would have adverse environmental impacts, including the embodied energy loss, demolition energy generation and waste production. Therefore, there is an urgent need to consider alternative scenarios for these massive concrete structures. Usually, if a structure becomes redundant and is retained, then its value and operational cost for new uses will need to be assessed. There are some examples of modern movement garages being demolished and replaced; Welbeck Street Car Park, built in 1971 in London and demolished in 2020, is planned to be replaced by a hotel. There may be good reasons for this, and these reasons need to be acknowledged. Several ideas and examples of reuses of multi-storey garages have been proposed where they are converted other uses, for instance, the Daimer Car Hire Garage (1931) and the Bluebird Garage (1924) in London were converted to offices. Usually there is an economic and social case for this. This thesis does not include the economic, environmental or social analysis relevant for the future of these structures, but focuses instead on the exploration of their adaptive reuse potential for CEA from the architect's perspective.

Numerous uncertainties associated with CEA constrain the architectural design for up-cycling buildings of this type of food cultivation. Considering design thinking as the main process leading to the development of a viable design proposal, three thematic categories have been identified through the literature review: planning, architectural and environmental, as the units of analysis that are crucial for providing knowledge on the design problem and defining the steps to be followed when problem-solving. Regarding planning limitations, the implementation of technical food systems in existing buildings requires innovations in urban planning documents (Sanyé-Mengual, Anguelovski, Oliver-Solà, Montero, & Rieradevall, 2016; Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall, 2015; Specht, Siebert, & Thomaier, 2015). A lack of experience in such practices results in regulatory gaps in the legal framework and often leads to the rejection of the agricultural proposal. The possibility to make an exception for a single case, or to change a planning approach, depends on the market, and the political, spatial and social circumstances of a city. Yet CEA operations are now appearing in cities and there remains a paucity of evidence on the benefits delivered by such productive systems within the urban sustainability framework. This causes misunderstandings, which leads to the prioritisation of investments that are considered more profitable or which have higher social value (Specht et al., 2015). Therefore, from the architect's perspective, the rejection of CEA as an alternative use of an existing building may form the first constraint for further design stages. When investigating the architectural thematic category, it becomes clear that despite the emergence of building-based CEA in cities, there remains a lack of evidence on the design aspects and elements of technical food systems (Jenkins, 2018). The existing CEA practices were constructed through trial and error, and did not provide communicable knowledge. From the architect's perspective, the lack of design information limits our understanding of how these systems should be designed to operate efficiently. Thus, the replication of any existing building-based CEA operation is difficult in any another context (Jenkins, 2018). This indicates a need to advance the research on building-based CEA by exploring and summarising the current state of knowledge, and generating data relevant to the architectural analysis of the adaptive reuse potential of the existing architectural type. The significance of the environmental category in the design thinking process arises from the fact that CEA is highly reliant on urban resources, predominantly energy (Kozai, Niu, & Takagaki, 2015; Thomaier et al., 2014; Togawa et al., 2014) and water (Ackerman, 2012), which not only puts pressure on the urban environment but also increases the financial investment. Existing research proposes resource-efficient technologies, alternative energy technology options and technical synergies which can be developed to reduce the resource impact of CEA operations. However, this knowledge is not summarised neatly, and is therefore difficult for an architect to apply in the design thinking process. Additionally, the exploration of the resource-efficiency of CEA operations (e.g. greenhouses) is more advanced in rural areas. While the existing studies consider the results of such studies as valid for urban applications (Montero, Baeza, Muñoz, Sanyé-Mengual, & Stanghellini, 2017), there has been no detailed investigation on utilising the findings when conceptualising design scenarios for up-cycling urban structures for CEA.

The planning, architectural and environmental thematic categories that arose as part of the inquiry in this research have not been explored in the context of repurposing inner-city modern movement car parking structures for CEA. Through adaptive reuse, this architectural type may gain significance beyond its original function and become the driver for an innovative design process. Exploring the up-cycling potential of multi-storey structures creates the foundation for investigating type-alterations required to accommodate CEA as one of the strategies that will allow these buildings to evolve to meet changing urban requirements and to prevent their demolition.

1.3. Aim, objectives and research questions

The aim of the thesis is to explore the adaptive reuse potential of inner-city modern movement car parking structures for viable controlled environment agriculture operation from the architect's perspective, and to determine the alterations within the existing architectural typology that are required to accommodate this innovative use as a response to changing urban demands.

Within this aim, the specific objectives of the research are:

Objective 1: To research and document the planning, architectural and environmental opportunities and limitations for up-cycling inner-city modern movement garages for CEA

Objective 2: To adapt the knowledge that has been generated for the development of the guide for the analysis of the adaptive reuse potential of inner-city modern movement garages for CEA

Objective 3: To apply the guide to specific test-cases of inner-city car parking structures in the UK to identify their up-cycling potential for CEA

Objective 4: To critically evaluate the inherent formal structural similarities developed between the series of case studies to conceptualise the alteration of the existing architectural typology

These critical areas of inquiry help to generate the two research questions which are identified below.

RQ 1: What is the adaptive reuse potential of inner-city modern movement car parking structures in planning, architectural and environmental terms, relevant at the initial stage of the architectural scenario development?

The basis and need for research question one is that no single study exists which conceptualises the up-cycling potential of inner-city modern movement garages for CEA from the architectural perspective at the initial stage of the design proposal development. Within this research area, planning, architectural and environmental opportunities and limitations play a critical role in deepening our understanding of the up-cycling process, including local authorities allowing the reuse of urban structures for CEA, designing a viable architectural proposal and selecting sustainable technologies which reduce the reliance of UA on urban resources. Therefore, Objective 1 aims to investigate the opportunities and limitations for the proposed adaptive reuse process from the architect's perspective through a literature review, case studies and interviews. The knowledge generated will create a theoretical background for the research. Objective 2 intends to adapt the data obtained for the development of a guide for the analysis of the adaptive reuse potential of inner-city car parking structures for CEA. The crucial goal of objective 3 is to apply the tool developed to the three strategically selected case studies in the UK. While the theoretical knowledge generated in the first phase of the thesis, conducted as research for design, is the foundation for the guide, the application of the tool leading to the viable architectural scenario development was conducted as research for design. The analysis of the findings from the guide's application will be then summarised and critically evaluated to specify the adaptive reuse potential of inner-city modern movement car parking structures in planning, architectural and environmental terms (Objective 3).

RQ 2: Which formal structural similarities arise from the analysis of the up-cycling potential of modern movement car parking structures that alter the existing architectural type in order to accommodate controlled environment agriculture?

The need for research question two arises from questioning the validity of the modern movement car parking structures in inner-city areas due to increasing requirements for land for development uses, which is considered more relevant than car parking. While various strategies for the enhancement of the local food supply are now being investigated, CEA may become one of the uses which justifies the adaptive reuse of this architectural type. This requirement for the evolution of the original function features modern movement car parks as catalysts for innovation, while simultaneously enabling this architectural type to gain significance regardless of their initial use. Although the concept of building-integrated agriculture in the context of adaptive reuse has been already analysed from various perspectives in the literature (Despommier, 2011; Gould & Caplow, 2012; Specht et al., 2013; Thomaier et al., 2014), no previous study has investigated the alterations which need to be implemented when up-cycling inner-city modern movement car parking structures for CEA. The conceptualised repurposing potential of multi-storey garages (Objective 3) will be critically evaluated to identify formal structural similarities developed within the planning, architectural and environmental phases of the design process, which alter the existing architectural type as a response to changing urban needs.

The relationship between the aims, objectives, research questions and research phases and methods are presented in Figure 1.

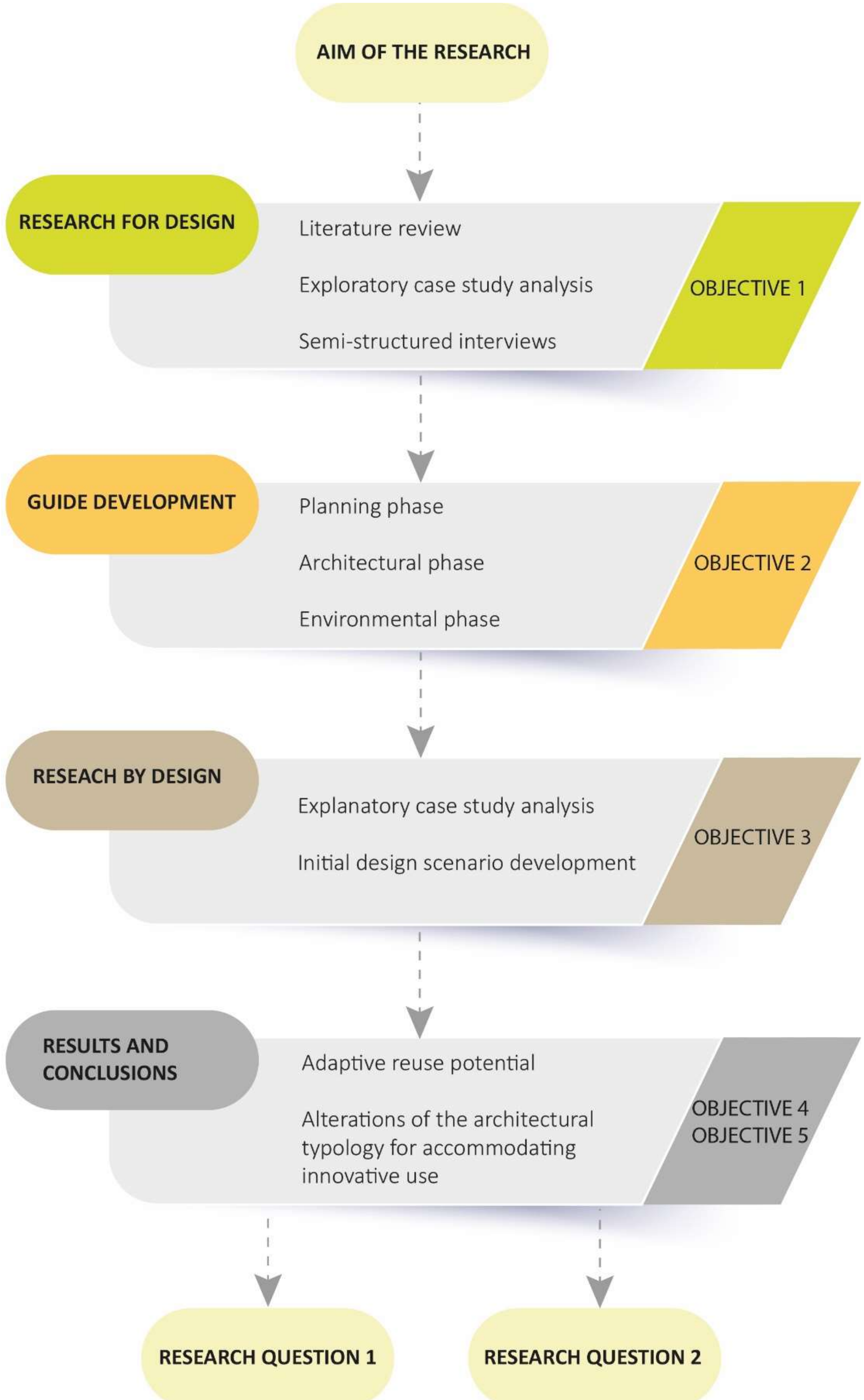


Figure 1: Aims, objectives and research questions in relation to research phases and methods, by Szopinska-Mularz

1.4. Structure of the thesis

The overall structure of the thesis takes the form of nine chapters. Chapter 1 introduces the scope and study area, the rationale for the research, the aims, objectives and research questions of the thesis, as well as indicating the limitations of the investigation. Chapter 2 discusses the methodology and introduces exploratory and explanatory case studies. Chapter 3 reviews the relevant literature from diverse and varied sources. These include books, peer-reviewed journal articles, reports and studies by government departments, professional associations and organisations, which investigate, and offer insights and guidance on the global food system, the domestic food supply in the UK, building-integrated agriculture, CEA, the adaptive reuse of buildings, the future directions of vehicular movement and car parking in cities, the past and future of modern movement multi-storey garages, as well as the opportunities and limitations for their up-cycling.

The two chapters which follow this lay out the theoretical dimensions of the thesis. Chapter 4 focuses on the exploration of books, peer-reviewed journal articles, reports and studies by professional associations and organisations on the planning, architectural and environmental aspects relevant for developing a viable design scenario for the adaptive reuse of buildings for CEA. The secondary data obtained are applied to three case studies to validate the knowledge gained and further investigate these practices from the planning, architectural and environmental perspective.

Chapter 5 centres the study on inner-city modern movement car parking structures. Primary data was gathered through semi-structured interviews with experts concerning their knowledge and perception of the proposed retrofit action. Analysing the results allowed the development of planning, architectural and environmental criteria, as well as opportunities and limitations to meeting these criteria when exploring the up-cycling potential of multi-storey garages for CEA. Investigating the findings from interviews offered crucial insights and recommendations for developing the guiding tool for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA.

The remaining three chapters focus on the empirical dimension of the thesis. Chapter 6 summarises and adapts primary and secondary data from chapters 4 and 5 for the development of a guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA. In Chapter 7, the guide is applied to three case studies in the UK. The findings from this exploratory stage of the research enable the conceptualization of viable initial up-cycling scenarios for the three case studies through the design thinking process.

Chapter 8 summarises and critically evaluates the findings of the research. First, the role of research for the design of CEA as an alternative use of modern movement garages is discussed. Second, based on the findings from Chapter 7, section 8.3 answers research question 1 by critically evaluating the adaptive reuse potential of these structures for CEA from the planning, architectural and environmental perspective, relevant at the initial stage of the design proposal development. Next the chapter presents reflections on the application of the guide to the selected case studies and discusses the role of research by design in this process. Finally, section 8.5 answers research question 2 by determining the formal structural similarities which alter the existing architectural typology to accommodate an innovative use.

The conclusions of the thesis are presented in Chapter 9, based on meeting the objectives of the research. The crucial conclusions are drawn concerning the planning, architectural and environmental potential identified for the adaptive reuse of inner-city modern movement car parking structures for CEA, and the innovative type-alteration that arose as a result. The chapter explains the significance of the findings, the contribution of the research, and challenges encountered in the development of the thesis. Finally, section 9.5 indicates the issues which remain unanswered, the new ones which have emerged, and makes recommendations for further investigation.

1.5. Limitations of the research

The research explores the adaptive reuse potential of inner-city modern movement car parking structures for CEA in the UK context, relevant at the initial stage of the architectural investigation. The specific focus on inner-city multi-storey garages arose as a result of the literature review, which indicated that the implementation of car restraint policies predominantly commences in central urban districts (Lawor, 2014; Litman, 2011; Nieuwenhuijsen & Khreis, 2016). Therefore, the obsolescence of car parks, built in the modern movement era to accommodate rapidly rising demand for parking, is now a growing phenomenon in inner-city areas. At the same time, the value of land and competing demands for spaces in central urban districts have become the main reasons for comparing the benefits of up-cycling with the demolition of these structures, even if they are still being used for car parking. This thesis is not a full cost-benefit analysis exploring whether this is viable, but rather an architectural exploration into the potential for this architectural type to accomodate CEA. The research concerns the initial stage of the design thinking process conducted by the architect, regarding the planning, architectural and environmental opportunities and limitations which enable exploring and conceptualising the viable initial design scenario for the proposed up-cycling. It is beyond the scope of this study to conduct a comparative value assessment of such up-cycling compared to demolition and new build. The data generated can be used for this purpose in the next step of the research, beyond the boundary of this thesis.

The secondary data gathered through the literature review on the planning, architectural and environmental opportunities and limitations, which should be considered by the architect in the initial stage of the scenario development for the proposed adaptive reuse for CEA, are limited to studies conducted in the temperate climatic zone in these cases, where climatic conditions alter the effects of the design aspects being analysed. This constraint arises from the scope of the research on the up-cycling potential of garages located in the UK. The applied criteria exclude literature on CEA operations located in tropical or polar regions, which require different architectural solutions. The specific focus area for the thesis is building-based hydroponic farming. Thus, the investigation excludes other building-based technical food systems, for instance, aeroponics or aquaponics.

The guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA, developed in Chapter 6, is limited to application at the initial stage of the architectural scenario development. Thus, the data generated should be used for engaging with the local authority, developing an initial design proposal of the CEA concept, including sustainable technologies. A full investigation of planning and architectural rules and regulations, as well as the specific environmental analysis relevant for the location of resource and energy-efficient technologies and alternative energy technology options, lies beyond the scope of this stage of the research. However, subsequent research in this area is recommended, which will investigate specific design development.

It is beyond the scope of this study to examine the structural capacity of the analysed car parking structures. In each case, and for each modern movement garage selected for adaptive reuse for CEA, structural assessment is required to explore the capacity of the accommodating urban form and to include structural alterations that reinforce the building. This thesis does not focus on such analysis, this must be conducted by an accredited structural engineer. Nonetheless, it is a prerequisite before making any design decisions in the next stage of the research.

Chapter 2: Methodology

2.1. Introduction to Chapter 2

This chapter introduces the research methodology. First, the philosophical and theoretical framework focuses on the role of research in the design process, which leads to innovative problem solving, and the alteration of certain typological elements of the modern movement architectural type in the development of procedures for the conceptualisation of an innovative architectural typology. Then the typological approach to architecture is discussed and situated within the framework of this research. Design thinking is proposed as the crucial process for design research focused on the development of an innovative architectural typology, which requires the adaptation of experimental, or even hybridised, methodologies. Second, design research is introduced. Third, the guide for the analysis of the adaptive reuse potential of inner-city car parking structures for CEA is introduced as the primary outcome of the theoretical investigation, and the selected case studies are introduced. Finally, research methods and data analysis techniques are discussed.

2.2. Philosophical and theoretical framework

At a basic level, this research focuses on the analysis of the opportunities and limitations relevant for making design decisions on up-cycling a specific architectural type for an alternative function. Thus, the research methodology incorporated aims to explore the concept of adaptive reuse from the typological perspective.

The etymological root of *type* comes from the Latin word *typus*: form, figure, image or kind, as well as the Greek word *typos*: impression, dent, blow or mark, effect of a blow. The Greek philosophical approach to *typos* encompasses the concept of the model as a combination of characteristics, which are present within a group of specific individuals. The terms *form* and *idea* which originate from in philosophical discourse are crucial for the notion of type in architecture. Plato equates the *form* to the *idea* and sets it in opposition to *experience*. He perceives forms as elements of the eternal word, and the models from which all things derive. In Aristotle's thinking, form and matter were indivisible components of one substance. Form exists in matter as an internal active principle, which shapes the matter seeking to transform into the actual form. This understanding of the concept of form triggered the idea that through the classification of such forms, insights into these underlying, governing principles can be made (Madrazo, 1995).

The modern understanding of *type* was initialised by Goethe, who begun to use the term *type* as a mere taxonomic category in the context of the natural world. Contemporaneously, Cuvier indicated that form is the ultimate criterion for categorisation (Madrazo, 1995; Vidler, 1978). The typological approach to categorise architecture was first embraced by Durand in the 18th century, while explicitly and systematically theorised in architectural discourse by Quatremère de Quincy in his book *Dictionnaire Historique d"Architecture,* published in 1832. Quatremère de Quincy based the conceptualisation of type on three pillars: origin, transformation and invention, where origin refers to the essence or nature of things. The author aimed to implement architectural typologies into practice, by conceptualising them in the context of need, use and custom, which refers to the idea of *charactere* developed in Enlightenment philosophy. The understanding that specific types of buildings represent symbols of their function by attributes of their *charactere* was first introduced into architectural theory by Germain Boffrand (Guney, 2007). According to Boffrand, *charactere* is defined as the expressive function of an urban structure to communicate with the observer. In his view, the arrangement, construction and decorative elements of a building should proclaim its destination (Kruft, 1994). Quatremère de Quincy acknowledged the role of a character in architectural typology as a principle identified within the building that arose from its fundamental purpose in the uses for which it is destined. In relation to the origin theory, architectural type could be interpreted as architectural etymology.

During the era of the modern movement, the perception of architectural typology was reinterpreted due to the changing social structure and the requirement for mass-production through standardisation in the post-war era. At that time, a type was seen as a production model for a series, rather than the series defining the type (Pevsner, 1976). Theorists and architects from the era of the modern movement, such as Gropius, widely criticised the definition of a type developed in the 19th century for being too immobile and static (Gropius, 1965). The role of history in the development of architectural typology was dominated by the capabilities of new materials and techniques, considered as outstripping any formal, typological laws (Samson, 2015). The modern movement discourse led to the reinterpretation of the type by distancing its significance from the use of the building. Consequently, architectural typology was relegated from its traditional deliverance and cultural value rooted in the underlying philosophical concept.

The philosophy of architectural typology further evolved in the 20th century, especially in the works of the Neo-rationalists. This Italian group, gathered around Aldo Rossi, Carlo Aymonino and Giorgio Grassi, emerged in the 1960s and focused their interpretation of type on the morphological and historical continuity of the city. The neo-rationalists applied typomorphological studies to the systemic investigation of buildings and the urban fabric itself, which led to the conceptualisation of architecture as an autonomous, self-referential discipline

(Madrazo, 1995). In his book *Architecture of the City* (Rossi, 1982), Rossi proposed an *autonomous urban theory*, where typology creates the *analytical moment of architecture.* Functionalism was rejected as the determinant of the architectural form, owing to the persistence of specific forms despite functional changes. Rossi indicates: *one is struck by the multiplicity of functions that a building of this type can contain over time and how these functions are entirely independent of the form* (Rossi, 1982, p. 29). He criticised functionalism as the determinant of form as naïve, and stated that if urban artifacts were able to renew and reform themselves by accommodating new functions, the architectural values of buildings would be easily available and continuous. As such, the transmission of a city as an element of a culture would be questionable, due to the impermanence of the architectural types. In this philosophical context, the architectural type obtained the potential to be the driving force behind a design process, where the alteration of specific typological elements arises as a response to changing urban demands. Therefore, through the requirement for urban evolution, the architectural typology rooted in history becomes the catalyst for innovation, while the type itself gains significance regardless of the original function. In this theoretical and philosophical framework, a design process for the adaptive reuse of a certain architectural type requires investigating the alterations which have to be implemented within the existing building in order to accommodate the new function. This research adopts this typological approach as a research methodology in order to critically evaluate the inherent formal and structural similarities developed between the series of case studies, and based on this, to conceptualise the evolution of the specific architectural typology originally developed for car parking.

2.3. Design thinking for addressing the research aims

When considering the research methodology for conceptualising the adaptive reuse potential of the existing architectural typology for an innovative function, it becomes clear that the procedures to achieve a viable design scenario are as yet unknown and un-researched. Working on innovations in architecture requires design thinking, which is understood as

a situated, contingent set of practices carried by professional designers and those who engage with designs, which recognizes the materiality of designed things and how they come to matter (Kimbell, 2015, p. 131).

Kimbell (2015) indicates that the ways in which professional designers solve a problem are of value both to businesses trying to implement innovation, and to societies trying to initiate change. To develop innovation, designers can no longer work as *the main agents in design* (Kimbell, 2015, p. 301). Solving an architectural problem requires the involvement of several discipline-specific experts, potential users and other stakeholders, who together contribute to the research, the generation of knowledge, and finally the design. Such a diversity of engaged actors emerges from the fact that the outcome of the architectural process is expected to deliver a context-specific, viable, but previously unknown solution, and often contributes to the social, economic and environmental sustainability of the urban environment. The multidimensionality of the design is deepened by the fact that architects work within the existing structural context. From the realist's perspective, such structures are conceptualised as pre-existing attributes of the world, which facilitate and limit individual action. However, individuals possess the ability to act in a way which is not entirely determined by social structures (Carter & New, 2004). This is related to Marx's statement that people *make their own history… but under circumstances existing already, given and transmitted from the past* (Marx, 1968, p. 96). Therefore, the potential development of the innovative architectural typology focused on urban food production as the adaptive reuse of an existing, but increasingly derelict typology of buildings, triggers the need to conceptualise viable architectural scenarios, which would contribute to a change in the manner of thinking about modern movement garages and urban food cultivation. This should be done by engaging with various actors and structures, as well as using diverse methods of investigation adjusted to the specificity of the project. In his book *Design Thinking*, Rowe (1987) states that the nature of the problem-solving process itself shapes the solution. In a similar vein, Schön (1983) indicates that framing and making moves in the design thinking process is vital for solving the problem, while Lawson & Dorst (2009) argue that the level of expertise among architects plays a crucial role in shaping the final design scenario. Collectively, these studies outline the critical role of the architect's knowledge of the design problem, and the steps that he or she follows when problem-solving for the development of the final architectural proposal. As this thesis focuses on an innovative architectural problem, the legitimacy of findings relies on the replicability of the knowledge generated for the defined research problem, which can be achieved through the development of the guide that informs architects, with different levels of expertise, how to frame and make moves within the design thinking process. The conceptualisation of such a tool requires experimental or even hybridised methodologies.

This investigation takes an inter-disciplinary approach, since it draws on various discipline-specific sources and methodologies. Adapting mixed-methods research principles allows one to gain both the specific advantages of the qualitative research, which provides *a great deal of descriptive detail when reporting findings* (Bryman, 2016, p. 394) and sees life as a process (Bailey, 1994), as well as quantitative methods, which help to provide evidence by recording solid information in numbers (Walliman, 2011). In particular, the research learns from a review of the literature on architecture, agriculture, urban planning and sustainable design, and uses methodologies intended for social sciences. Such an approach arises from the need to generate, interpret and understand data which belongs to diverse disciplines, which have to be unified in order to deliver knowledge on an innovative architectural typology focused on urban food production. The results are supported by evidence which is validated through triangulation of methodologies.

2.4. Research design

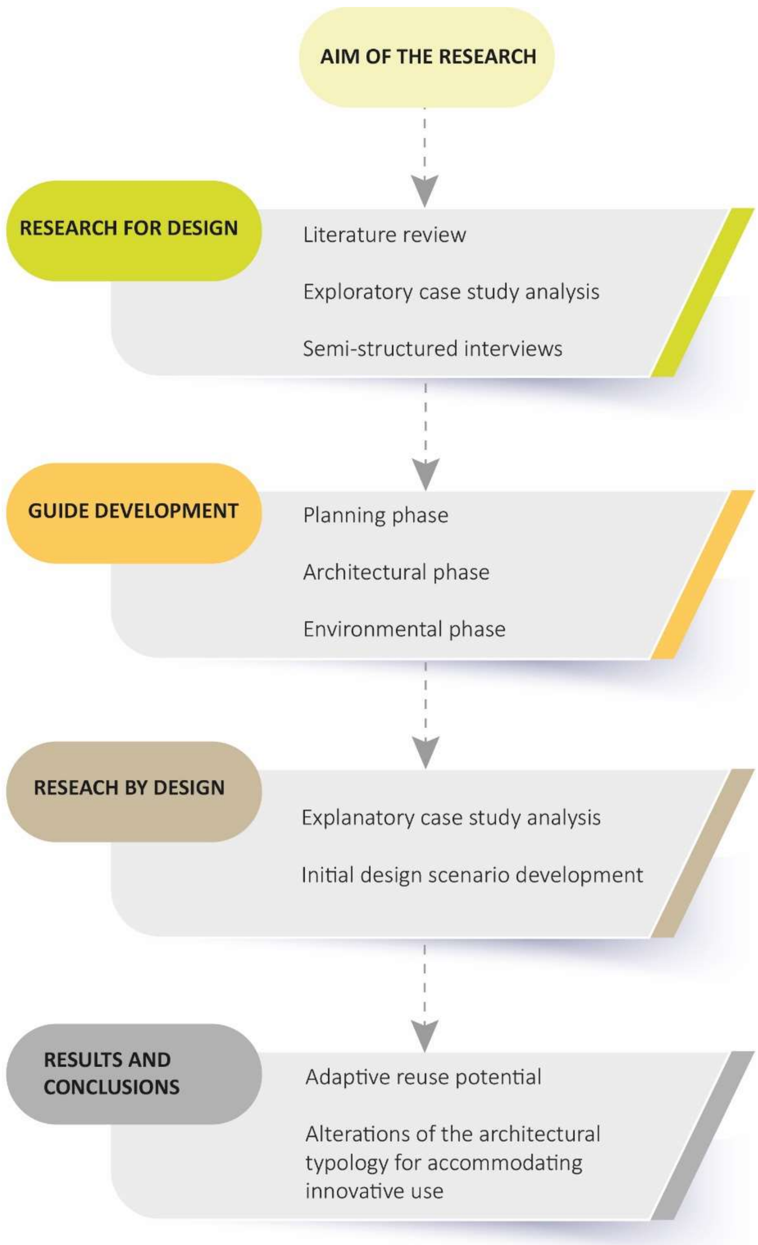


Figure 2: Research design, by Szopinska-Mularz

The research design is presented in Figure 2. The first part of this investigation can be called research for design, which according to Forlizzi, Stolterman, & Zimmerman (2009) represents *several different kinds of theory that all have been produced with the intention of being applied in the practice of design* (Forlizzi et al., 2009, p. 2892). The main aim of research for design is to link theory building with the perspectives of design science, to generate theory from practice, to propose models for the construction of theory from other perspectives, and to develop tools for theory construction as well as theoretical imagination escalation (Friedman, 2003). Findings and conclusions which often arise from research for design include guiding philosophies, conceptual frameworks, design implications emerging from the exploration of people and contexts, as well as design implications resulting from the investigation of designed artefacts (Forlizzi et al., 2009). These theory-driven tools contribute to the understanding of the design problem, thus becoming the foundation of a viable practice.

In this thesis, the research for design led by the design thinking process consists of the triangulation of the essential theoretical and empirical material investigation. The empirical analysis is grounded in the literature review and the findings are validated through their investigation within the case studies. The analysis of the semi-structured interviews narrows down the research to the specific type of urban structures and contributes to theoretical knowledge generation. The data obtained are then summarized, and conclusions are drawn for developing a guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA operations. Applying the tool just established to specific test cases of inner-city parking structures located in the UK is the beginning of the empirical investigation, which allows the replication of the findings from the theoretical study, and further validates them. This analysis is conducted as research by design and focuses on the initial design scenario development for the proposed up-cycling. Research by design:

concerns the various ways in which research and design are interconnected when we produce new knowledge through the act of designing. (…) Research by design opens for research contributions, which are both normative and directed towards the future, and introduces a holistic approach to design as well as research (Jorgen, Martin, & Mette, 2013, p. 336).

Research by design is considered as a practice, which addresses the future through the proposal, model or experiment (Jorgen et al., 2013). Allen (2009) argues that research by design is contrary to a theoretical investigation, which *(…) points towards the past, whereas material practices analyse the present in order to project transformations into the future* (Allen, 2009, p. XVIII). While the theoretical investigation conducted prior to the evolution of the guide attempts to understand the nature of the phenomena being analysed, the practical analysis addresses the future through architectural proposal development. This empirical element of the thesis leads to the discussion on the planning, architectural and environmental opportunities and limitations for up-cycling inner-city modern movement garages for CEA. As Jorgen and colleagues indicate, research by design *presents a model for thinking the generalising and rule building while simultaneously projecting towards the future* (Jorgen et al., 2013, p. 336). In this thesis, applying the guide based on theoretical knowledge leads to the conceptualisation of the adaptive reuse potential of the modern movement architectural type and the identification of the type-alterations required to accommodate an innovative use. The steps of the thesis are presented in Figure 3.

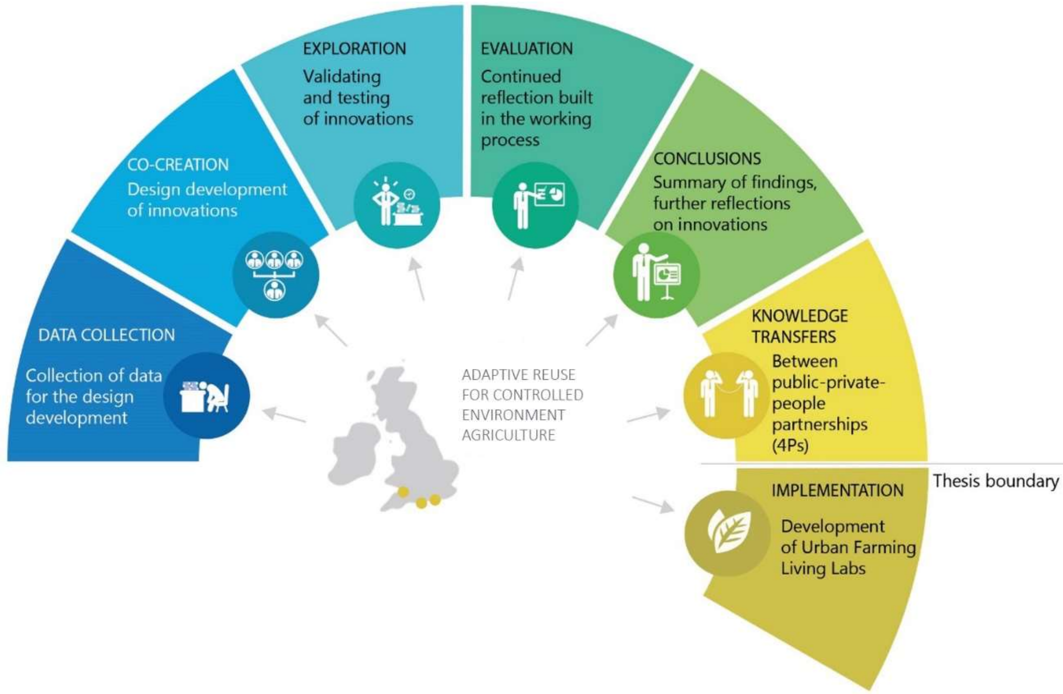


Figure 3: Steps of this thesis, by Szopinska-Mularz

The crucial process of research by design is the architectural analysis of selected cases of inner-city modern movement garages. The architectural analysis aims to explore the adaptive reuse scenario, which in the given dynamic urban and architectural context arises as a plausible strategy for the future of this architectural type, and within its capabilities addresses and respects the requirements of the city. According to Eisenman (1963), architectural systems evolve from external situations as well as internal functional requirements. Architectural analysis therefore allows us to investigate these systems as three-dimensional volumes, developing in space and time, which are open to various internal and external forces, leading to distortion and deformation (Eisenman, 2018). According to these principles, the architectural analysis of existing car parking structures investigates opportunities and limitations for repurposing them for CEA, which arise as the results of the interviews with experts (Chapter 5).

To achieve the aims of this thesis, a mixed-method approach was selected, which includes quantitative and qualitative elements. This approach is taken according to Corbin and Strauss (2015), who indicated that the structure of the methodology should reflect the aim of the research. Applying a mix of methods to gather data from different sources contributes to the validity of the findings by generating complementary data from which to draw conclusions

(Greene & Caracelli, 2016). In this research, a mixture of methods was required to combine the qualitative and quantitative data that was obtained from the literature investigated and from case studies of CEA operations, as well as from the interviews with experts who could provide context and depth to our current understanding within practice.

2.5. Guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for controlled environment agriculture

The guide is the tool which evolved in this thesis as the result of research for design. The overarching aim of the tool is to enable the replication of the theoretical findings from this research in the process of exploring the up-cycling potential of modern movement garages for CEA, and to lead the design thinking process when developing the initial design scenario. The guide points out planning, architectural and environmental criteria, steps and tools, and summarises and presents data that allow for the architectural exploration of various scenarios for the adaptive reuse of multi-storey garages for socially, environmentally and economically viable CEA operations. The guide is divided into three phases according to the categories that arose and were analysed through the theoretical exploration of primary and secondary sources. These are the planning, architectural and environmental phases. Findings from the interviews with experts conceptualise the planning, architectural and environmental criteria for the viable architectural scenario development, which can be explored by applying the two steps formulated for each of the categories to the selected car parking structure. This requires specific tools and software that are used by architects to obtain knowledge through descriptive and graphic analysis. Using the guide for theory-driven architectural scenario development generates case-specific explanatory data and conclusions for the alterations required to the modern movement architectural type to accommodate this innovative use.

2.6. Initial design scenario for the adaptive reuse of the inner-city modern movement car parking structure for controlled environment agriculture

The application of the guide for the analysis of the adaptive reuse potential of modern movement car parking structures for CEA to three strategically selected cases of multi-storey garages in the UK resulted in the development of initial design scenarios for their future. These scenarios, also termed proposals in this thesis, consist of the planning, architectural and environmental phases. In the planning phase, the initial design proposal for up-cycling the structure analysed for CEA reveals the key drivers and motivations for its adaptive reuse for CEA, which are summarised descriptively. The architectural phase is informed by the planning phase and conceptualises the initial design scenario using graphic and descriptive methods. The architectural design scenario includes the results of the architectural investigation of plans, sections and axonometries of the car parking structure being analysed. The planning and architectural phases are the foundation for the environmental phase, where the proposal for resource-efficient technologies, alternative energy technology options, and environmental synergies with other uses is conceptualised descriptively. The initial design scenarios that were developed were then critically evaluated to conceptualise both the adaptive reuse potential of the modern movement architectural typology for CEA and required type-alterations.

2.7. Methods of data collection

2.7.1. Literature review

A literature review of secondary sources developed the theoretical background for this research. While selecting these sources, the crucial criterion was the review of literature concerning the opportunities and limitations relevant from the architects' standpoint on the initial stage of the development of the design scenario for up-cycling urban structures for CEA. The literature review aimed to capture the essence of the topic within the comprehensive interdisciplinary field and accumulate a relatively complete census of sources which are of relevance at the initial stage of the adaptive reuse proposal conceptualisation. The exploration was focused on academic sources, including peer-reviewed journal articles and books as well as professional literature, including guidelines and reports for urban farmers. The relevant literature was searched through the library, library website, Google Scholar, Web of Science and NGO websites.

The review on opportunities and limitations for the adaptive reuse of buildings for CEA is divided into three conceptual sections, each forming a category relevant for the initial architectural scenario development as identified in the literature. These are planning, architectural and environmental considerations. The planning analysis investigated those sources which explored and documented the notion of the adaptive reuse of urban structures for CEA from the perspective of urban farmers and stakeholders. Thus, to gather relevant data, research conducted through interviews with these groups of experts was given priority. This approach allowed for analysing and documenting planning opportunities and limitations for up-cycling urban structures for UA which arose when engaging with local authorities. Another selection criterion was to investigate reports written by professional organisations which support urban farmers by offering guidance. The planning section of the literature review concerns the urban scale of the research. The next section focuses on the architectural level of the investigation. The architectural exploration commenced with the review of academic sources which contribute to the specific type-recognition of building-integrated CEA. That allowed for the distinguishing of types of CEA operation which integrate this productive technique within and upon existing urban structures as a framework for exploring the literature on the opportunities and limitations created by the architectural form for CEA, the orientation of that form, the materials to enclose a space for CEA and the role of the structure of the building that has been adaptively reused for CEA. The selection of literature was focused on academic sources, which explore these thematic categories in the temperate climatic zone through the framework of environmental sustainability and the productivity of the agricultural system. While in previous studies CEA was mainly investigated in a rural context, the literature focused on such applications is considered valid for urban applications (Montero et al., 2017; Sanyé-Mengual, Cerón-Palma, et al., 2015). Finally, the environmental investigation reviewed the literature on resource and energy-efficient technologies and alternative energy technology options which can be integrated with CEA operations to minimise their reliance on urban resources and to reduce the financial investment. For this investigation, literature which analyses these technologies in relation to CEA under the temperate climatic zone was selected. Another criterion focused the research into sources concerning the integration of sustainable installations with existing urban structures. This is because the adaptive reuse of buildings for CEA can be conducted as an energy retrofit, which minimises the reliance of technical food systems on urban resources and reduces any associated costs. The environmental opportunities and limitations analysis concerned the architectural level of the research. The findings from the literature review were then validated and tested on case studies of existing building-based CEA practices and in interviews with experts.

2.7.2. Interviews

Semi-structured interviews were chosen as a research method for generating primary data for this thesis. The main aim of the interviews was to narrow down the research to the specific type of urban structures: modern movement multi-storey garages located in the inner-city areas. The primary data generated led to the distinction of criteria which should be met in the design process in order to develop viable architectural scenarios for the proposed adaptive reuse, as well as opportunities and limitations for this process. Scientific interviews were chosen as a method of research for design, the questions were formulated and discussed by the architect and from design thinking perspective.

The sampling of experts for interviews was based on the following criteria:

- Sustainability officers and urban planners (public administration officers) in Portsmouth, Bristol and Brighton & Hove;
- Experts in the sector of architecture, urban design and urban regeneration;
- Experts in the sector of building-based CEA;
- Researchers in the field of architecture and UA.

Participants were selected with the aim of understanding their points of views, experiences and visions concerning three main thematic categories related to up-cycling inner-city modern movement car parking structures for CEA: planning, architectural and environmental opportunities and limitations. The diversity of professional backgrounds of the interviewees resulted in their various contributions to a specific category of questions. For instance, sustainability officers and urban planners brought more significant insights to the planning category, while conversations with architects focused on more detailed design aspects. The professional experience of the participants, and their significant position within organisations, ensure that their points of view and visions are informed, and therefore their opinions can be considered sufficiently reliable for the purpose of this research. As such, their responses expand and consolidate findings from the literature review, as well as indicating implications for the development of the guiding tool.

Fifteen semi-structured interviews were conducted from October 2018 to January 2019 as face-to-face, Skype or telephone conversations. The way the interview was carried out was affected by the distance between the interviewer and the respondent. Before the interview, the relevant documentation (e.g. plans of the car parking structures selected for the case study) was sent to the interviewee by email. Interviews lasted between 40 and 90 minutes, and were audio-recorded to retain an uninterpreted and full version of the discussion. Subsequently each interview was transcribed for the data analysis. This approach was approved by the University of Portsmouth Ethics Committee (Appendix D).

2.7.3. Case study

Hancock & Algozzine (2017) suggest that through case studies, researchers gain in-depth understanding of phenomena and their meaning. Merriam & Tisdell (2016) argues that insights which arise from case studies can influence procedures, policy and future research. Case study research is applied twice in this thesis. First, specific cases of existing building-based CEA practices are investigated in Chapter 4. This exploratory method of analysis (Yin, 1993) was chosen for validating findings from the literature review on planning, architectural and environmental opportunities and limitations which arise when up-cycling buildings for CEA. Second, the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA was applied to three strategically selected multi-storey garages in Chapter 7 to further validate and replicate findings from the theoretical exploration. This investigation is explanatory (Yin, 1993) and led to the conceptualisation of the formal structural similarities which alter the existing architectural typology to accommodate an innovative use as a response for changing urban demands.

2.8. Selection and introduction of the cases

The crucial selection criteria for the exploratory case study research conducted in Chapter 4 was the utilisation of an existing inner-city structure located in the temperate climatic zone for UA, where the crop cultivation is carried out using technical food systems. While the main aim of these case studies was to validate theoretical findings from the literature review on planning, architectural and environmental opportunities and limitations for the design scenario development, the diversity of the cases selected was required for testing the data generated in various contexts. Ideally, the knowledge obtained should be applied to each type of building-based CEA operation developed in Chapter 4 Figure 25. However, the FF is only introduced in theoretical research. Thus, as there is no actual significant example of an FF, this type of CEA is excluded from the case studies.

The potential case studies were explored through documentation analysis, including online sources (e.g. the websites of the UF practices) and city plans. While the data and documents, such as architectural plans, that were required for this investigation were difficult to obtain in many cases, managing directors had to be contacted through email or Skype and were asked to provide relevant documentation and knowledge. Thus, the availability of data relevant for the analysis became a crucial case study selection criterion. Finally, Grow Bristol in Bristol (UK), Biospheric Project in Manchester (UK) and BIGH Ferme Abattoir in Brussels (Belgium) were selected. The diversity of planning, architectural and environmental approaches applied, as well as the various development stages of the selected cases, allowed for the extensive validation of the theoretical findings from the literature review.

The criteria for selecting the case studies required for explanatory research, through applying the guide that was developed in Chapter 6, included evaluating the specific characteristics of the city (the area, population and population density) and development goals, future directions for traffic and parking in the inner-city, and the state of the local food supply. The investigation was based on analysis of the relevant documentation, including city plans, planning documentation, planning guidance, development frameworks, local food supply reports, future strategies and site visits. When choosing case studies, priority was given to cities with a strong emphasis on sustainable urban development and the advancement of a sustainable local food system. The diverse urban contexts and circumstances under which building-based UA can come into existence was considered an advantage for the case study selection. Differences between the case studies allowed for testing the efficacy of the theoretical findings from this research in various urban background, which led to the development of a variation on the adaptive reuse scenarios. A review of similar case study research has shown that three case studies are considered sufficient, given the research timeframe, to evaluate findings and draw conclusions (Caputo, 2013; Hancock & Algozzine, 2017; Merriam & Tisdell, 2016).

Applying the criteria discussed leds to the selection of three cities to achieve the main aims of the study: Portsmouth, Bristol, and Brighton & Hove. These urban areas were chosen as they are representative cases of coastal cities of different size and population density (Table 1), they are a similar distance from the capital city London. and all are located in the south of England (Fig. 4). The strong emphasis on the sustainable future of these urban areas and the development of a sustainable food system arose as crucial opportunities for up-cycling buildings for CEA within their inner-city areas. Furthermore, their temperate, mild and maritime climate benefits the implementation of innovative farming practices as both open-field and indoor agriculture. The selected locations allow for the development of CEA to increase local summer crops as well as winter production that requires lower energy input for heating, in contrast to cooler parts of the UK.

Figure 4: Map of the geographical location of the three cities selected for the case study

Table 1: Portsmouth, Bristol and Brighton & Hove: relevant data for the case study selection. Sources: Portsmouth City Council 2012; Bristol City Council 2011; Brighton & Hove City Council 2009

	Portsmouth	Bristol	Brighton & Hove
Area	40.25 km²	110.07 km²	87.54 km²
Population	207,100	428,200	273,400
Population density	5028/ km²	3890/ km²	3445/ km²

When investigating car parking structures in the UK, the crucial section criteria included construction in the modern movement era (1900-1980) and the inner-city location of the garage. Diverse architectural characteristics, such as unique architectural elements or a spatial and functional connection with other uses, were interpreted as an opportunity for variability within the development of adaptive reuse scenarios.

The case study research focuses on the inner-city areas of Portsmouth, Bristol, and Brighton & Hove, where the following modern movement multi-storey garages were identified (Table 2):

1. The Isambard Brunel Car Park in Portsmouth: a single-function structure,
2. The Prince Street Car Park in Bristol: a multiple-function structure consisting of a car park and the Bristol Hotel,
3. The London Road Car Park in Brighton & Hove: a multiple-function structure. Three apartment buildings (Mayflower Square) and two sports fields are located over the London Road multi-storey car park.

Table 2: Portsmouth, Bristol and Brighton & Hove: relevant data for the parking garage selection

	The Isambard Brunel Car Park	The Prince Street Car Park	The London Road Car Park
City	Portsmouth	Bristol	Brighton & Hove
Date of construction	1970	1966	1976
Number of parking storeys	5	5	3
Number of car parking spaces	468	297	528

2.8.1. Introduction of case studies selected for the exploratory research

This subsection introduces three cases of existing inner-city building-based CEA practices developed from up-cycling existing urban structures. These operations will be investigated in Chapter 4 in order to validate the findings from the literature review on the planning, architectural and environmental opportunities and limitations which arise when up-cycling buildings for CEA.

Case study 1: Grow Bristol

Grow Bristol (Fig. 5) is a hydroponic farm established in 2014 in Bristol in the UK. The enterprise is located on derelict land in the inner-city used on a meanwhile lease basis. The place was selected to grow the product close to the consumer and to enable a just-in-time supply of a fresh product. The cultivation of microgreens and leafy crops is carried out all-year-round in two previously used 45 ft (13.72 m) shipping containers that are lit solely by artificial lighting sources. The first container accommodates seeding and harvesting facilities, as well as an entrance area where the cloakroom and disinfection space is located. In the second container, hydroponic installations are placed on two racks, each of which contains three tiers. The second container also provides space for research and experimentation (Grow Bristol, 2019).

Figure 5: Grow Bristol, Bristol, UK, The arrangement of hydroponics in a shipping container. Photo: Szopinska-Mularz 2018

Grow Bristol uses the ebb and flow hydroponic system to cultivate leafy greens. An air conditioning device controls the internal environment of the farm through optimising air temperature and relative humidity. The primary lighting source for the plants is high-pressure sodium lamps. The crops are harvested twice a week, then packaged, labelled and delivered by bicycle to groceries and restaurants within Bristol. Growing in shipping containers using hydroponic technology allows the production of 20 kg of high-quality leafy greens a week. To promote hydroponic cultivation and inform about the technology, Grow Bristol offers educational opportunities and organises farm tours. Moreover, to expand food production on the local level, the team offers consulting services with a focus on choosing the appropriate system design, developing an individual operational toolkit, and connecting with the urban agriculture industry (Grow Bristol, 2019).

Case study 2: The Biospheric Project

The Biospheric Project was an experimental urban farm designed and constructed by Andrew Jenkins, Natalie Hall and Greg Keeffe from Queen's University Belfast for the Biospheric Foundation and presented at the Manchester International Festival 2013. The farm was built in

Irwell House, which was a derelict industrial three-storey building on the banks of the River Irwell in Salford, England. The design team was not involved in planning procedures as the Biospheric Foundation organised this. One of the primary goals was to create a living lab, where researchers could test innovative environmental practices and technologies for urban food cultivation. The research team left the project in 2013 and passed on the management and maintenance to the Biospheric Foundation Community Interest Company, which however closed in 2015 (Jenkins, 2018).

Experimenting with urban food production in Irwell House focused on aquaponics, which was considered a more sustainable technology than hydroponics due to the reduced need for water and energy resources. Significant benefits, which were taken into consideration and which surpassed a hydroponic system, were the development of a self-regulating ecosystem, minimised human interaction, the potential to harvest fish, and the opportunity to improve waste streams in the urban environment (Jenkins, 2018).

The technical conditions of the building were considered the major limitation for implementing aquaponic installations. While two automotive garages occupied the ground floor of Irwell House, the aquaponic facility had to be installed above the ground level. The placement of the system was preceded by a structural assessment, which led to the conclusion that the most substantial elements of the system (filtration unit and fish tanks) should be arranged above the primary steel beams on the second floor (Fig. 6). As plant growing units, a window system was built on the five south-facing windows on the second floor of the building (Fig.7,8,9) and the Quonset shape rooftop greenhouse (RTG) (70m^2) with the NTF system was installed. The RTG, made of PE-based film, utilised sunlight for plant growth, while a hybrid lighting system consisting of existing windows and artificial lighting illuminated the aquaponic farm. The system was stocked with common carp and red Nile tilapia. The selection of crops included tomatoes and peppers in the façade system, and leafy greens in the RTG. Alongside this, a façade-farm was designed as a prototype using a hydroponic double helix NFT system, where crops were grown within the cavity built between the two glazed surfaces of the double-skinned façade (Jenkins, 2018).

The long-term goal of the urban farm was not only to produce healthy food but also to benefit the local community by providing an educational space, which might contribute to the improvement of social cohesion and the creation of a sense of ownership in the area. Each stage of the project, from design to crop harvesting, was open to the public and was considered an experimental space instead of strictly a food production zone. The farm was presented at the Manchester International Festival 2013, which included a two-part aquaponic workshop organised by the design team. Finally, after the festival, the research team planned to pass the management and maintenance of the urban farm to the local community, thus contributing to the development of green jobs in the areas (Jenkins, 2018).

The development of the urban farm in Irwell House did not include any alternative energy sources. Systems such as PV panels or water harvesting were considered a significant contribution to the environmental sustainability and financial viability of the aquaponic farm, however in order to be installed, financial and other resources from sponsors would have had to be noticeably more generous (Jenkins, 2018).

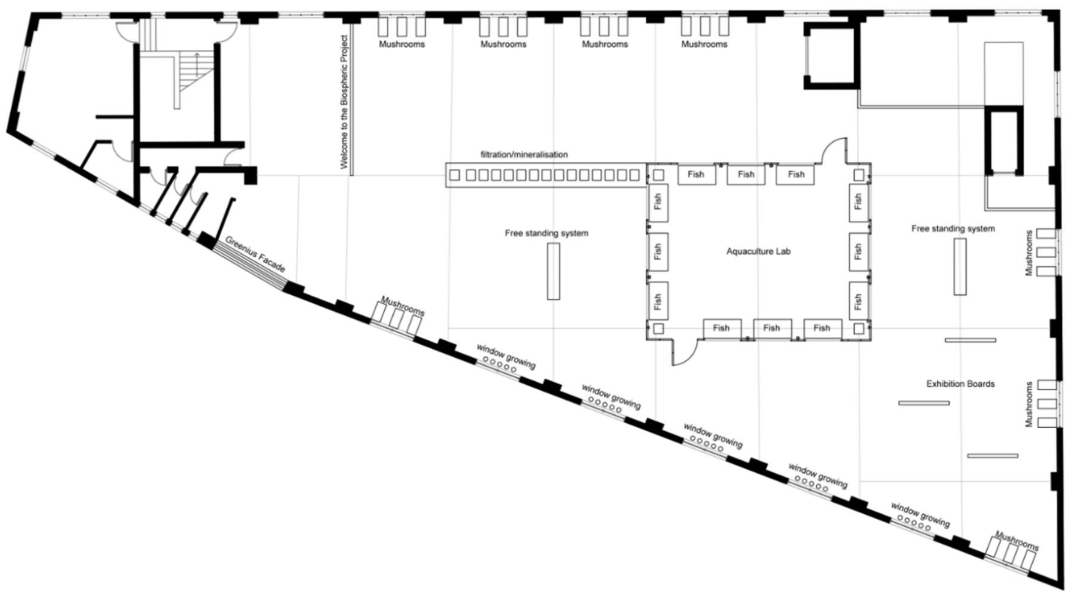


Figure 6: The Biospheric Project, Irwell House, Salford, UK, 2nd floor layout. Source: Jenkins 2018

Figure 7: The Biospheric Project, Irwell House, Salford, UK, Filtration units. Photo: Jenkins 2018

Figure 8: The Biospheric Project, Irwell House, Salford, UK, The interior with fish tanks and window growing units, 2nd floor. Photo: Jenkins 2018

Figure 9: The Biospheric Project, Irwell House, Salford, UK, Window growing system. Photo: Jenkins 2018

Case study 3: BIGH Ferme Abattoir

Figure 10: BIGH Ferme Abattoir, Brussels, Belgium. Photo: Lateral Thinking Factory 2018

BIGH Ferme Abattoir is an aquaponic farm located in Brussels, Belgium. The farm was developed on the rooftop of the Foodmet market hall (Fig. 10) and comprises of two areas: a 2000 m^2 outdoor garden and a 2000 m^2 high-tech three-zone greenhouse. A closed-loop aquaponic system is used to cultivate fruits, vegetables, herbs and fish. The farm is zero waste. The idea for developing the BIGH Ferme Abattoir concentrated on the cradle-to-cradle approach and circular economy principles. Analysis showed that the existing Foodmet market hall was underused and upgrade-ready. Up-cycling the building allowed for extending the exploitation phase of its lifecycle by reusing the rooftop and reducing the environmental impact of the development (Fig. 11) (BIGH Farm, 2018).

The primary goal of up-cycling the existing Foodmet market hall was to develop a productive eco-system, which has minimal environmental impact and allows for year-round production. This approach was significant for the first stage of the development, which included the sustainable upgrade of the existing building and the design of a productive space on the rooftop. Most architectural modifications were conducted on the rooftop level (Fig. 12,13), such as the construction of a greenhouse, a fish production area with a fish processing and packaging rooms, a biofilter area, two transparent plastic greenhouse tunnels (470 m^2 and 174 m^2), a workspace and a coolroom. The existing second-floor rooms were converted to staff facilities. A further 2000m^2 space on the rooftop was designed as an outdoor garden, which in the future will be complemented by a restaurant (BIGH Farm, 2018).

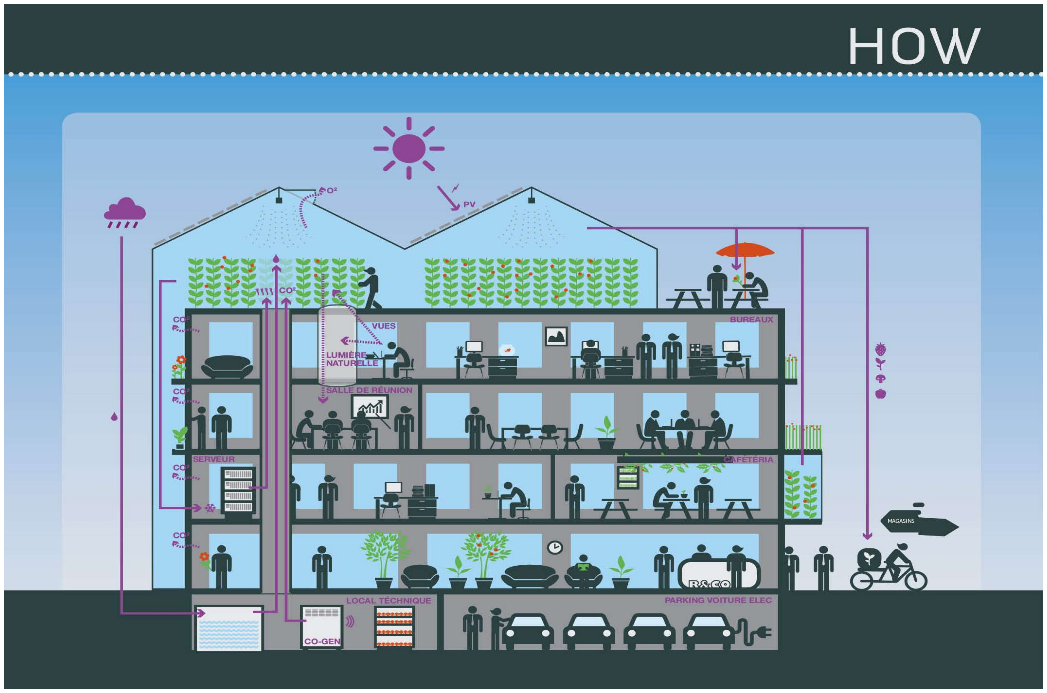


Figure 11: BIGH Ferme Abattoir as a productive eco-system. Source: Lateral Thinking Factory 2018

To reduce the impact of high energy consumption and greenhouse gas emissions from the farm and the Foodmet market hall, energy-efficient lighting, PV panels located in an adjacent building, industrial waste heat exchange, energy-efficient pumps and boilers, rainwater harvesting and a closed-loop plant cultivation system were developed. The farm creates a synergy system with the Foodmet market hall by using a heat pump, which captures heat and offers refrigeration to the cold rooms in the market hall. The pump is complemented by a gas heating device, which provides CO_2 for supporting photosynthesis during the day (BIGH Farm, 2018).

Each year, the BIGH farm produce 35 tonnes of striped bass fish, without the use of chemicals or antibiotics. The 1500 m^2 production space allows for the cultivation of tomatoes, organic herbs, microgreens and red berries. While the productivity potential of the farm depends on cultivated plant species, sizes, temperatures and adapted systems, the company is looking for innovative technologies to make production more efficient. For instance, tomatoes are cultivated in Growbags by Greenyard, and organic herbs are grown on tidal tables with additional LED lighting to allow year-round production (BIGH Farm, 2018). To achieve economic viability based on fresh product sales, BIGH is working closely together with other local enterprises, for instance Atelier Groot Eiland, who runs a restaurant and food shop in the neighbourhood. Moreover, new job opportunities in UA and manufacturing activities are available, including employing disabled people through cooperation with the social partner TRAVIE. Several tours with different purposes are offered, including educational excursions for children and consultancy opportunities for professional farmers (BIGH Farm, 2018).

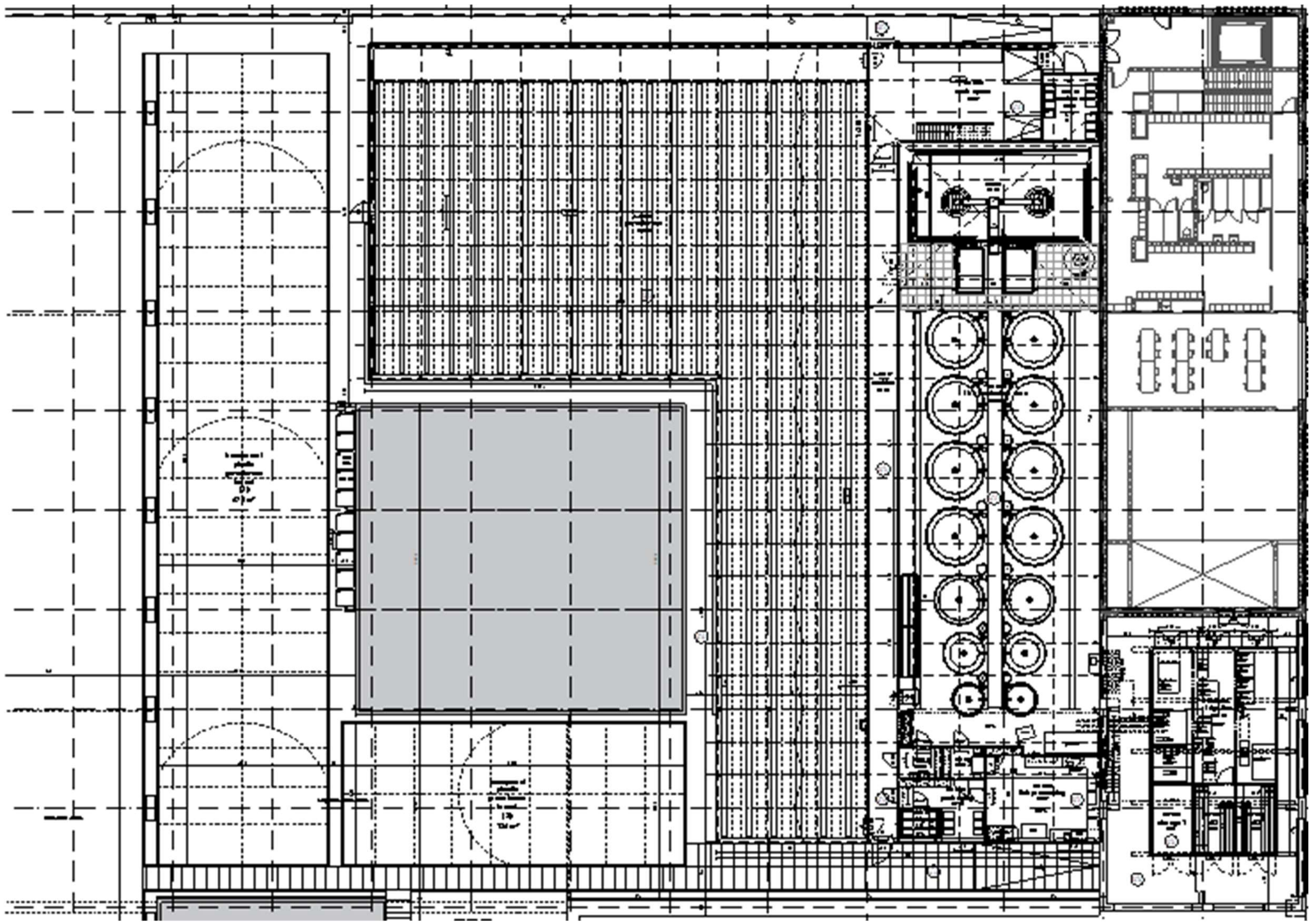


Figure 12: BIGH Ferme Abattoir, Brussels, Belgium, New construction rooftop layout. Source: Lateral Thinking Factory 2018

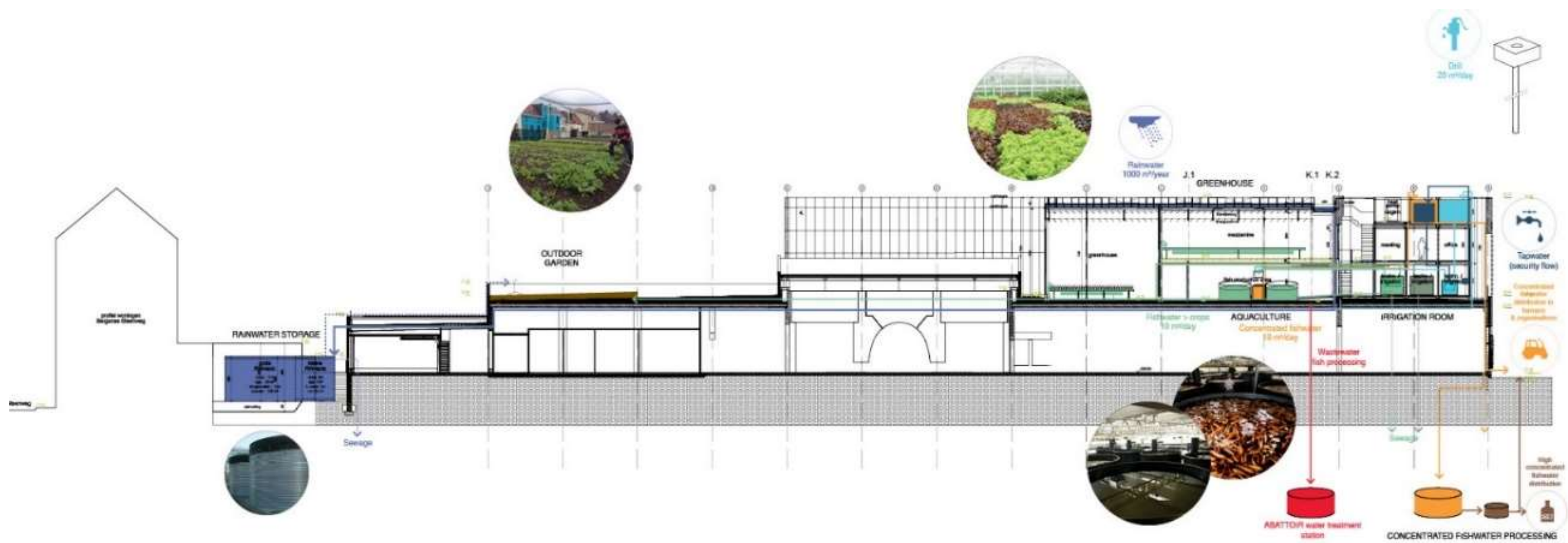


Figure 13: BIGH Ferme Abattoir, Brussels, Belgium, Section. Source: Lateral Thinking Factory 2018

2.8.2. Introduction of case studies selected for the explanatory research

This section introduces the three inner-city modern movement car parking structures in the UK chosen for the explanatory case study. In Chapter 7, the guide for the analysis of the adaptive reuse potential of this architectural type for CEA will be applied to these strategically selected cases.

Case study 1: Portsmouth

Portsmouth is one of the major urban areas located on the south coast of the UK, with an estimated population of 207,100 across 40.25km². A population density of 5028/km² makes Portsmouth the most densely populated urban area in the UK outside of London (Portsmouth City Council, 2012). The development of the city has been strongly influenced by its predominantly island location and its connection to the sea. Portsmouth has been the Royal Navy's base since the 17th century. This maritime heritage is recognised as an active driver of the local economy. The ferry port and the naval dockyard offer several jobs and generate essential income (Portsmouth City Council, 2012).

Although Portsmouth developed as a strategic centre providing employment, health care, higher education and shopping facilities in the South Hampshire sub-region, the analysis conducted by the City Council has not identified opportunities for urban extensions (Portsmouth City Council, 2012). This is because of the island location and the high building density, leaving very few large sites available for development. To support the quality of life of residents and the built and natural environment of the city, the Portsmouth Core Strategy (Portsmouth City Council, 2012) aims to continue densifying the city and increasing the compactness of the urban fabric as a strategy towards sustainable urban development. In the current context, these alterations generate competition between uses, increase the value of land, and contribute to the reduction of green spaces within the city.

Future directions for traffic and parking in the inner-city of Portsmouth

While only three main roads link Portsea Island with the mainland, this connection, and the strong dependence of urban residents on private vehicles, represent the leading cause of traffic congestion in Portsmouth. The prognosis for the future presented in the Western Corridor Transport Study (Portsmouth City Council, 2010b) indicated that planned housing and commercial growth would increase inbound traffic in the a.m. peak by 41 percent, the majority of which would be generated along the western corridor and on the M275 leading towards the city centre. The predicted increases in traffic congestion would create problems and constraints for businesses, delivery operations, bus reliability and air quality in the inner-city (Portsmouth

City Council, 2012).

Plans for traffic and parking in the central area of Portsmouth focus on the reduction of private car use through the enhancement of public transport and low-carbon mobility, as well as improvements to the Park & Ride zones and to their connection with the city centre (Portsmouth City Council, 2012). *The Portsmouth Plan* (Portsmouth City Council, 2012) links these targets to the urban regeneration strategy of the inner-city, as they are expected to bring economic and social benefits to the district. While priority is given to mixed-use development in the city centre, this would generate further traffic issues and increase the demand for off-street parking (Hampshire County Council, 2013; Portsmouth City Council, 2012). Thus, the strategic decisions and actions on transportation and parking need to be delivered simultaneously as elements of the regeneration of the area (Hampshire County Council, 2013). To contribute to that goal, *The Portsmouth Plan* (Portsmouth City Council, 2012) presented the strategy to redesign the highway network in the north of the inner-city and give priority to public transport passengers, cyclists and pedestrians. While the main shopping area of the city centre is already pedestrianised, the document does not assume further car use restrictions and indicates the crucial role of vehicular access and off-street parking, including the Isambard Brunel Car Park, for the competitiveness of the district. Taken together, these findings indicate that the adaptive reuse of the Isambard Brunel Car Park for alternative use is a scenario for a distant future.

Local food supply in Portsmouth

Portsmouth is one of the largest fruit handling ports in the UK, with fruit supplied from the Caribbean, Morocco, South Africa, Central and South America, New Zealand and the eastern Mediterranean. A review of the food system in Portsmouth (Food Matters, 2015) revealed that there is no commercial agriculture within Portsmouth. The local food supply system depends on diverse producers in Hampshire, who supply vegetables and fruit for grocery stores in Portsmouth. For instance, Waitrose and the Southern Co-operative are supplied locally by over 75 small-scale producers from the Hampshire area.

Currently UA in Portsmouth is operating as small-scale initiatives, mostly as allotments or community gardens. The productivity of these activities is not considered as a contribution to the local food system. However, the social benefits of UF are acknowledged by the local authority and promoted, especially in housing areas (Portsmouth City Council, 2015). For instance, the Supplementary Planning Document-Food Growing (Portsmouth City Council, 2015) offers recommendations for planning officers, developers and community groups regarding the location of UA within the city, as well as design and technical aspects to be considered when planning food cultivation spaces. The guidance arose as an addendum to the sustainable urban development goals, where the use of land is identified as a strategy to bring multiple benefits. Thus, the strong need to encourage and guide UF initiatives in the densely populated urban area of Portsmouth is driven by several objectives defined in policies, for instance:

- *Encouraging and enabling healthy choices and making Portsmouth a sustainable city* (Portsmouth City Council, 2012, p. 13);
- *Promoting the sustainable use of energy, water and land* (Portsmouth City Council, 2010, p. 9,13);
- *Incorporating lifestyle features in housing that cut emissions and encourage food production* (Portsmouth City Council, 2009, p. 1);
- *Delivering sustainable communities set in a quality low carbon environment* (Portsmouth City Council, 2009, p. 19);
- *Creating an age-friendly city by encouraging healthy lifestyle choices which promote physical, emotional and mental wellbeing* (Portsmouth City Council, 2010a, p. 19).

Despite the support of the local authority, the implementation of in-soil UA practices is continuously challenged by the competing demands for space and high land value, as well as urban soil contamination and degrading ecosystem services (Portsmouth City Council, 2015). While the Supplementary Planning Document Food Growing (Portsmouth City Council, 2015) lists sites possible for conversion for food growing, these opportunities are mostly identified as in-soil cultivation techniques. The potential for integrating UA within existing buildings is recognised in internal areas of commercial developments, residential rooftops and balconies. The adaptive reuse of urban structures is not identified as a strategy for spreading UA. However, considering the current building density in Portsmouth, the Supplementary Planning Document Food Growing (Portsmouth City Council, 2015) indicates the need for conceptualising innovative forms of food cultivation as a strategy to reconcile ongoing urban development with UA, both required for improving the quality of living. Thus, up-cycling the Isambard Brunel Car Park may become a way to bring food production to the inner-city of Portsmouth.

Isambard Brunel Car Park

Isambard Brunel Car Park is located in the city centre of Portsmouth. The building was designed by the Council Architect W. Worden, and constructed in 1971 as a five-storey single function concrete structure where 468 parking spaces are located. Each storey of the car park is connected through a system of ramps, and complemented with two concrete staircases (Fig. 14), with lifts located in the northern and southern elevations, and one steel staircase in the middle of the eastern elevation. The typical floor height is 2,90m (Fig. 15). Solid walls partly secure the ground level of the car park. Other levels are limited by steel and concrete railings, which allow for natural light to penetrate the interior. The roof of the garage is flat and free from installations.

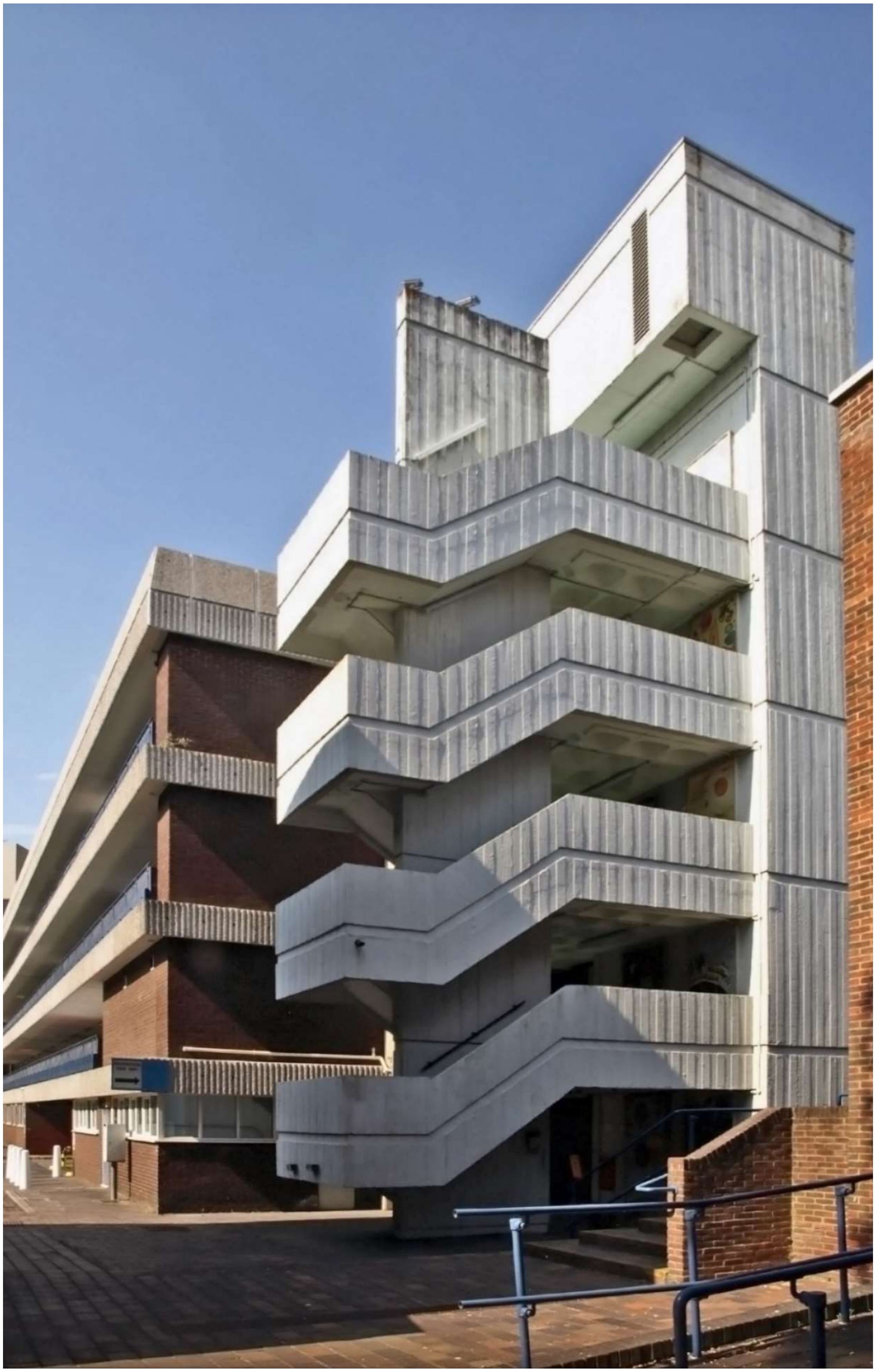


Figure 14: Isambard Brunel Car Park, Portsmouth, UK, Concrete staircase. Photo: Szopinska-Mularz 2019

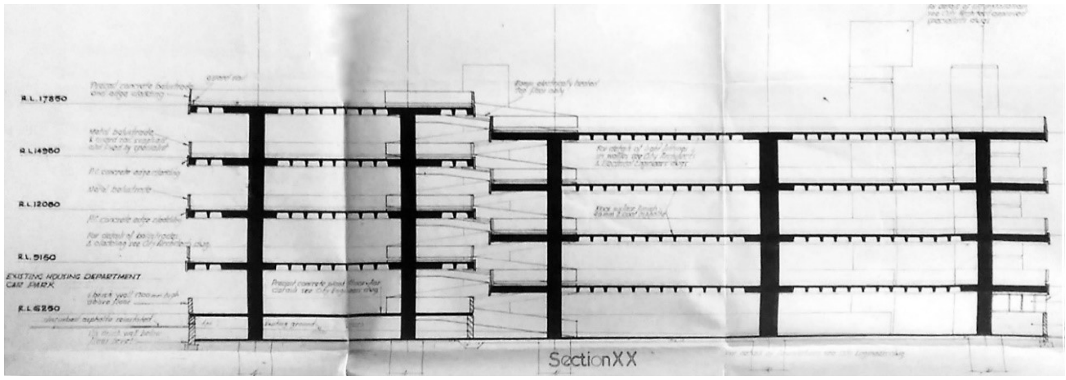


Figure 15: Isambard Brunel Car Park, Portsmouth, UK, Section XX, Source: Portsmouth City Council

Case study 2: Bristol

Bristol is one of the eight core cities in England, and the largest urban area in the South West region, with an estimated population of 428,200 over 110.07km² (Bristol City Council, 2011). The city centre is the primary employment area in the sub-region, offering approximately 109,500 jobs (2007). According to the Bristol Development Framework (Bristol City Council, 2011), Bristol's population is expected to grow to 519,800 by 2026. This expansion is projected to be accompanied by increased traffic congestion, more urban sprawl, decreased affordability of home ownership and relatively high levels of economic exclusion. To deal with these issues, social, environmental and economic goals have been introduced in planning documents. First, there is an aspiration for Bristol to become the leading European city for innovative enterprise, industry, culture, lifestyle and urban design, and environmental quality, which would reinforce its position as a Green Capital and a European Science City. The improvements developed within the city aim to enhance the specific physical characteristics of Bristol, which makes the city attractive for investments in future industries. Second, the balanced urban renewal strategy, which protects the built and historic environment of Bristol, enhances it by implementing high quality sustainable urban design and ensuring attractive places through the city, is recognised as a strategy aimed at reducing the adverse impacts of urban development. A significant goal is to protect the natural environment and green open spaces during the process of urban renewal and densification. Third, the shift to mixed-use development connected by the public transport network is indicated as the strategy that contributes to the enhancement of sustainable communities within the city. The crucial improvements are focused on a reduction in private car dependency and a boost in walking, cycling, rapid transit, buses and rail. Finally, the city aims to reduce its environmental impact by shifting to the low carbon economy in transport, homes and businesses, and increasing the use of energy from renewable and low carbon sources. This is expected to increase the resilience of Bristol to the challenges and consequences of climate change and peak oil (Bristol City Council, 2011). These goals create the foundation for the development of the spatial strategy for the future of Bristol, which includes space for UA as an element of green infrastructure contributing to residents' health and wellbeing, offering educational opportunities and enhancing wildlife.

Future directions for traffic and parking in the inner-city of Bristol

Reducing the impact of traffic and promoting of alternative mobility is one of the main objectives formulated in the Bristol Development Framework (Bristol City Council, 2011). The strategy highlights the role of enhancing the connection between public spaces in the city centre through walkable streetscapes to *reduce carbon emissions; support economic growth; promote equality of opportunity; contribute to better safety, security and health; improve quality of life and a healthy natural environment* (Bristol City Council, 2011, p. 80). The promotion of low-carbon mobility is supported by strategic actions in current planning documents, aimed at a reduction in, and restrictions to the parking supply, for instance, by indicating that new development in the Old City area should not further increase the levels of general traffic entering the district (Bristol City Council, 2011, 2015a). While short-stay parking is essential for business development in the area, long-stay parking is planned to be limited to operational needs (Bristol City Council, 2011, 2015a).

While the pedestrian-centred model of urban design is the priority in the inner-city, an essential level of transport is accepted in policies and design strategies. The Public Realm and Movement Framework (Bristol City Council, 2012) proposed an inner access loop route running around the city centre as an element of rapid transit. The route will be complemented by vehicular access zones which allow entering the area for operational servicing and parking purposes. Prince Street, where the car parking structure selected for the case study research is located, is part of a system of rapid transit running through the Old City. The street aims to provide frequent and fast public transport service, access for private cars and operational servicing in the strategic area of Bristol (Bristol City Council, 2011). As the Prince Street Car Park is located in the rapid transit zone, the structure can be easily accessed and may be expected to provide facilities for various modes of private mobility. Considering all of this evidence, it seems that the adaptive reuse of the Prince Street Car Park may be possible in the nearest future if the alternative usage delivers benefits for the sustainability of the inner-city.

Local food supply in Bristol

The leading local food suppliers for Bristol are located in Bristol, Somerset, Gloucestershire and Wiltshire. In the report *Who feeds Bristol*? *Towards a resilient food plan*, Carey (2011) revealed that the local provision of food to Bristol is insufficient, which indicates that the area of agricultural land required to produce food for the city is greater than the land area of the sub-region. However, the report (Carey, 2011) reveals that food could potentially be cultivated on

2,000 hectares of land within Bristol, including existing allotments, farmland and smallholdings, a proportion of council-owned green fields and brownfields, a proportion of land within private gardens and school grounds and 20 percent of parks and green space. Within the current urban development context of Bristol, crucial challenges for the implementation of UA in these sites are the competing demands for space and the growing value of land, which gives priority to more cost-effective investments. These issues contribute to a reduction in the existing agricultural land area within the city. For instance, 10,000 houses are planned to be built in south Bristol and supplemented by a Park and Ride area on grade-A agricultural land (Bristol Food Network, 2009).

Several organisations arose in Bristol to support and enhance a local food economy and increase understanding of social, environmental and economic benefits delivered by the local food supply to the city and its residents. For instance, Bristol Food Network contributed to this goal by formulating the Sustainable Food Strategy (Bristol Food Network, 2009) which highlights a supportive relationship between producers, suppliers and communities from the intra-urban and peri-urban areas as a priority, which supports the health and well-being of communities and provides a food supply system for Bristol. The sustainable and resilient vision of the local food supply in Bristol presented by the Bristol Food Network (2009) is based on three long-term aims:

(1) all residents are able to access and afford food that has been produced by local farmers and producers with respect for the health and wellbeing of the environment, animals and local communities, and sold by a diversity of collaborative local businesses;

(2) all residents know much more about where their food comes from and the impact their food choices have on all those involved in supplying their food and really value and enjoy the local produce they are buying;

(3) all residents have pride in their City being nationally recognised as an inspirational example of a diverse, vibrant, thriving food culture based on Bristol's myriad sustainable food initiatives (Bristol Food Network, 2009, p. 1)

The Sustainable Food Strategy (Bristol Food Network, 2009) highlights innovative approaches as being crucial for delivering the programs listed above. The role of the innovation is strongly emphasised as innovative production methods and models carried out as commercial and community operations are identified as opportunities to incorporate food growing spaces into urban design. Up-cycling the Prince Street Car Park selected for the case study research in Bristol may become a way to conceptualise one of the innovative models of inner-city food cultivation.

Prince Street Car Park

Prince Street Car Park (Fig. 16) was designed by Kenneth Wakeford, Jarram & Harris, and constructed in the Old City of Bristol in 1966 as a five-storey structure, where 297 car parking spaces are located. The multi-storey garage was initially built for the adjacent Unicorn Hotel, now called the Bristol Hotel. In 1994 the garage was overbuilt. Thus, the rooftop of the structure is now occupied by the hotel facilities.

Prince Street Car Park is a concrete structure. The east and west elevations are designed as a highly permeable geometric composition of X-components (Fig. 17, 18). The north elevation is the negative pattern of the east and west and the fourth side is a party wall. On the ground floor, the concrete lattice of the east and west elevations is propped up by V-shaped supports. Each storey of the car park is connected through a system of ramps, and complemented with one staircase adhering to the north elevation. The ground floor height is 3.20m and the upper typical floor height is 2.50m.

Figure 16: Prince Street Car Park, Bristol, UK, Façade. Photo: Szopinska-Mularz 2019

Figure 17: Prince Street Car Park, Bristol, UK, The geometric composition of X-components on the west elevation. Photo: Szopinska-Mularz 2019

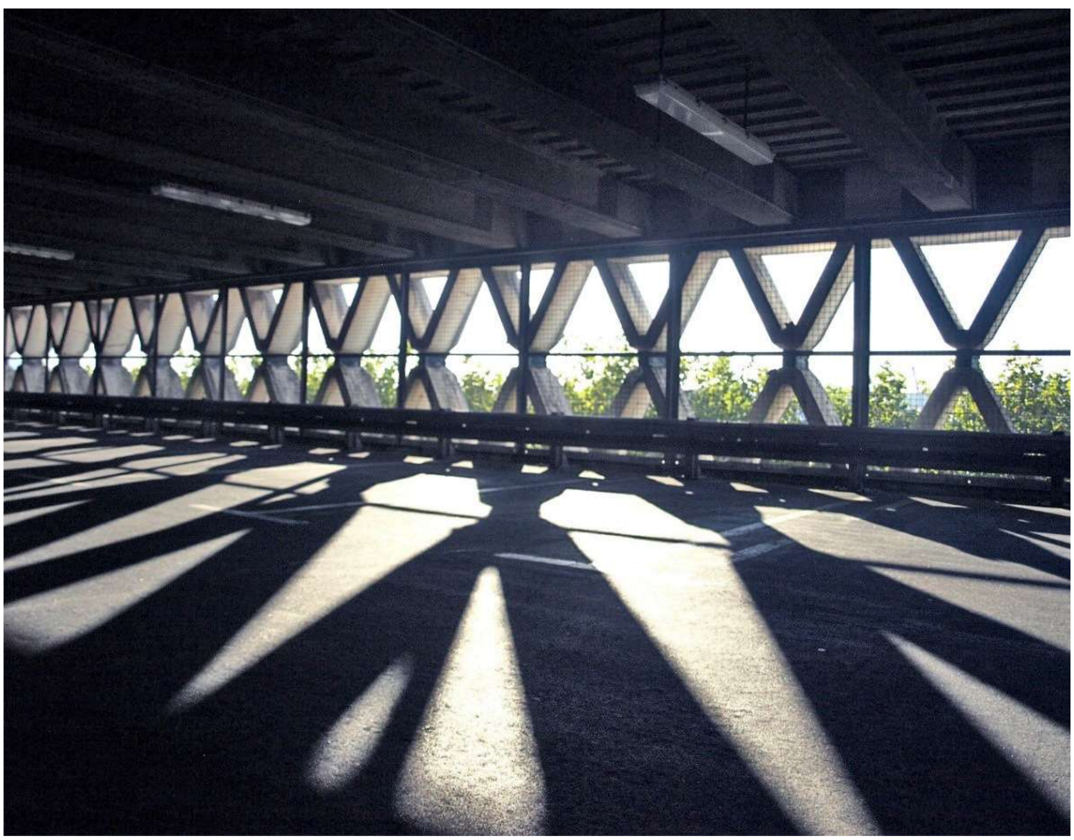


Figure 18: Prince Street Car Park, Bristol, UK, The geometric composition of X-components on the west elevation from the perspective of the interior. Photo: Szopinska-Mularz 2019

Case study 3: Brighton & Hove

The administrative area of Brighton & Hove covers approximately 87.54km² with an estimated population of 273,400. By 2030, the population is expected to grow by 10.2 percent (Brighton & Hove City Council, 2009). The central area of Brighton & Hove extends from Brighton Station to the seafront. It is a mixed-use and densely built-up district. The seafront is heavily urbanised and acknowledged by the English Heritage as one of the finest British urban seafront townscapes (Brighton & Hove City Council, 2015). While the city is located between the sea and the South Downs National Park, this places spatial limitations on any further urbanisation. Thus, future development plans focus on upgrading and further densifying the existing urban fabric. The implementation of mixed-use structures is encouraged, especially in areas where the poor-quality buildings are identified. The urban renewal plans support existing and new open spaces to increase urban greenery and biodiversity (Brighton & Hove City Council, 2009). A fundamental development principle for the inner-city of Brighton & Hove is to reduce the carbon footprint of the city, calculated as 5.14 global hectares (gha) per person in 2015 (Brighton & Hove City Council, 2015). The target set by the city (Brighton & Hove City Council, 2015) is to minimise its ecological footprint to 1.25 gha per person and to reduce its carbon footprint by 80 percent by 2050. One of the strategies to achieve these goals includes placing restrictions on private mobility and encouraging the shift to alternative transport modes.

Future directions for traffic and parking in the inner-city of Brighton & Hove

The Local Transport Plan (2015) for Brighton & Hove highlights the role of transport infrastructure in delivering long-term economic priorities within the Greater Brighton City Region. The City Plan (Brighton & Hove City Council, 2016) responds to the transportation requirements of a growing local economy and a growing urban population. The established priorities include meeting the demand for reliable and good quality transport infrastructure, and services which rely on sustainable options. These goals are reflected in the London Road Central Masterplan (Brighton & Hove City Council, 2009), which defines priorities for the inner-city, where London Road Car Park, selected for the case study analysis, is located. While vehicular movement plays a substantial role within the district, the main aim is to provide convenient connections to destinations within and adjacent to the area, as well as to improve access to multi-storey garages located in the district. The need for parking space in the inner-city creates a significant limitation for the adaptive reuse of London Road Car Park. However, the London Road Central Masterplan indicates the requirement to refurbish the building, or replace it within broader comprehensive development located in the area. Conceptualising the architectural scenario for up-cycling the garage would create a foundation for the assessment of the alternative future of this modern movement structure.

Local food supply in Brighton & Hove

In the report *Spade to Spoon: Digging deeper* (Brighton & Hove Food Partnership, 2012), it has been evaluated that approximately 70,000 hectares of agricultural land is required to supply Brighton & Hove with the required amounts of food. While the global food chain is expected to deliver the majority of this land, it is a crucial goal to increase the local food supply. This is because excessive dependence on the global food system is associated with the growing social, environmental and economic issues in Brighton & Hove, including the high rate of obesity (43,600 obese adults in 2010), diet-related diseases, the high ecological *foodprint* of the city (26 percent of the city's ecological footprint) and falling employment in agriculture in the region. Brighton & Hove Food Partnership (2012) defined nine strategic aims for the city, to be achieved by the enhancement of the local food supply system:

Aim 1: People in Brighton & Hove eat a healthier and more sustainable diet

Aim 2: All residents have better access to nutritious, affordable, sustainable food

Aim 3: The city has a vibrant, sustainable food economy of thriving local businesses, local products and employment opportunities

Aim 4: Public organisations have healthy, ethical and environmentally responsible food procurement policies and practices

Aim 5: More food consumed in the city is grown, produced and processed locally using methods that protect biodiversity and respect environmental limits

Aim 6: Waste generated by the food system is reduced, redistributed, reused and recycled

Aim 7: Local and sustainable food is promoted and celebrated by residents and visitors

Aim 8: High-quality information, support and training on sustainable food and nutrition issues are readily available. There are networking opportunities to encourage links between sectors

Aim 9: Local policy and planning decisions take into account food issues, and the city is engaged with national campaigns (Brighton & Hove Food Partnership, 2012, p. 6)

To contribute to these aims, both community and commercial UA initiatives are encouraged. Although the strategy assumes a concentration on in-soil farming techniques, the social, environmental and economic opportunities for the implementation of building-based UA are also identified. For instance, Aim 5 establishes the importance of identifying investment possibilities for developing UA. Aim 7 indicates the need to increase the amount and visibility of domestically produced food as well as building connections between producers and consumers. Aim 9 highlights the importance of educating the local authority on UA, and including UF in the city's planning processes. The adaptive reuse of an inner-city building for CEA has the potential to derive from, and contribute to, the aims formulated by Brighton & Hove Food Partnership (2012) as a secondary local food source.

London Road Car Park

London Road Car Park is located in the London Road Central Area of Brighton (Fig. 19). It was opened in December 1976 as a three-storey garage with 530 car parking spaces. There is a significant height difference between Providence Place, where the entrance to London Road Car Park is located, and New England Street, where the exit is. These levels are connected through a system of ramps and two staircases inside the car-parking structure, and the external staircase. On the rooftop of the garage on the New England Street level, there are three multifamily buildings (Mayflower Square) and two sports fields.

The north-eastern and north-western elevations of the structure are designed as permeable walls, with unique vertical concrete elements which separate the interior from Providence Place and York Hill. The south-eastern elevation is partly permeable. The south-west elevation is created by an atrium, which extends from the ground level of Providence Place to the New England Street level (Fig. 20). The south-eastern section of the building was developed as a ramp, where car-parking spaces are also located (Fig. 21).

Figure 19: London Road Car Park, Brighton & Hove, UK, Façade. Photo: Szopinska-Mularz 2019

Figure 20: London Road Car Park, Brighton & Hove, UK, Atrium between New England Street and the south-west elevation of the car parking structure. Photo: Szopinska-Mularz 2019

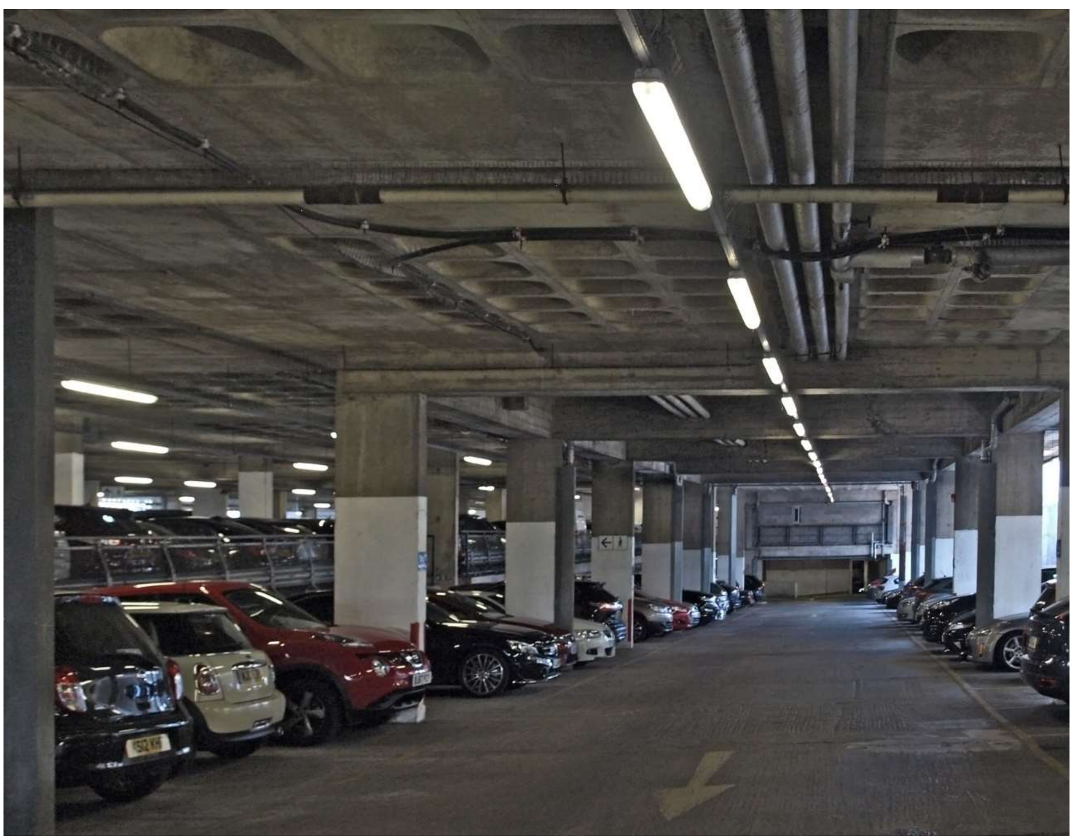


Figure 21: London Road Car Park, Brighton & Hove, UK, The south-eastern section of the building developed as a ramp. Photo: Szopinska-Mularz 2019

2.9. Data analysis

2.9.1. Literature review

The secondary sources in this thesis have been analysed from the perspective of three thematic categories: planning, architectural and environmental, which have been distinguished between in order to explore opportunities and limitations relevant for the adaptive reuse of urban structures for CEA. The selected secondary sources were downloaded and indexed using Microsoft Excel. The review of the literature was conducted through close readings, and coding explored opportunities and limitations under the thematic categories using NVivo 12. The developed juxtaposition of qualitative and quantitative evidence from empirical studies was then interpreted and summarised in tables.

2.9.2. Exploratory case study analysis

The exploratory case study analysis commences with the investigation of the selected building-based CEA operations. This includes the analysis of data provided by the managing directors of these initiatives, websites, and a PhD thesis based on one of the cases. This stage descriptively summarises the urban and architectural context of selected building-based CEA practices, the technical food systems used, the sustainable technologies applied and social involvement. Photographs, taken by the researcher or obtained by the managing directors, serve as visual sources which contribute to the conceptualisation and understanding of up-cycling urban structures for indoor food growing.

In the second phase of the analysis, findings from the literature review were applied to the case studies. This is divided into three sections: planning, architectural and environmental. In the planning phase, case studies were explored through the framework of planning findings from the literature review, which led to the determination of benefits derived from their development on the urban level. Then, the research focuses on the architectural investigation of the case studies. First, the three selected car-parking structures were analysed through the theoretical architectural framework that arose from the literature review. Data on the typology of CEA operations, architectural form for CEA, the orientation of that form, materials to enclose a space for CEA and the structure of the building adaptively reused for CEA were explored and are summarised in a table. Second, the knowledge obtained was used for the architectural investigation, conducted as research for design. Such analysis was done as an architectural analysis, which was developed in the form of a matrix. The crucial aim of the matrix is to expand theoretical knowledge on the adaptive reuse of buildings for CEA by concentrating the investigation on existing UF operations. This includes research on the urban and architectural approaches represented by case studies, the external cladding materials used, sunlight transmission availability and the structure of the accommodating architectural form. The findings indicate how units of analysis identified through the literature review affect the viability of CEA operations. Placing case studies within a theoretical architectural framework contributes to the architectural level of the research. Finally, the investigation moved to the environmental phase, which analysed selected CEA operations through the theoretical environmental framework that arose from the literature review. The findings, summarised in a table, contribute to the architectural level of this research.

2.9.3. Interviews

Interviews were investigated through content analysis, which is a technique for generating inferences from existing records in a systematic manner, or for exploring the views of groups or individuals by applying a definite number of categories, derived from a set of coding rules (Krippendorff, 2018; Weber, 1990). As such, content analysis enables the investigation of a large number of sources, and the categorisation of commonly occurring terms (Krippendorff, 2018). However, interpretation bias or incorrectly defined categories can undermine the validity of the findings (Weber, 1990). Overcoming such problems requires the development of a coding scheme, which defines the procedure for the categorisation and analysis of data (Weber, 1990). In this thesis, the interview questionnaire was the foundation for the coding scheme's development. The main coding categories relate to the thematic categories that arose from the literature review, as crucial from the architect's standpoint for the initial architectural scenario development. These categories are planning, architectural and environmental. Each of these is divided into subsections of opportunities and limitations. The coding scheme was developed in the software NVivo 12, which was used for the analysis of the interviews.

After coding the interviews, the thematic subsections were explored separately to gain closer insights into each of them. The specific limitations and opportunities identified by interviewees were listed in Microsoft Excel in relation to the thematic categories and subsections. During the development of the interview analysis chart, the number of interviewees who expressed a given opinion was noted to calculate the percentage of respondents that provided identical insights. This quantitative analytical process allowed for grading, prioritising and organising the opportunities and limitations identified regarding the frequency of their emergence in the interviews.

The crucial finding from the interview analysis was the development of planning, architectural and environmental criteria which the design process should meet in order to develop a viable architectural scenario for up-cycling inner-city modern movement car parks for CEA. The identified opportunities and limitations for meeting the criterion were listed in the category-specific table. The relevance of each opportunity and limitation was determined by providing the percentage of respondents who indicated its significance for the proposed up-cycling. Ultimately the analytical process generated both qualitative and quantitative data, essential for the development of the guide for the analysis of the adaptive reuse potential of modern movement garages for CEA. The contribution of the interview analysis was twofold. First, it produced the knowledge which was integrated into the guide to inform architects on the planning, architectural and environmental aspects crucial at the stage of the initial scenario development. Second, the interviews defined the features which the architectural guide for the analysis of the up-cycling potential of inner-city modern movement garages for CEA should possess.

2.9.4. Explanatory case study analysis

The explanatory investigation commenced with the exploration of the urban context of the case studies. This included documentation analysis on the specific characteristics of the city (the area, population and population density) and development goals, future directions for traffic and parking in the inner-city, and the state and aims of the local food system. Then, the modern movement garages were explored from the architectural perspective, through the design thinking process. To conduct such an analysis, the plans of selected car parking structures were obtained from city councils (Portsmouth City Council, Bristol City Council and Brighton & Hove City Council). While the researcher was only allowed to photograph the documentation, the plans were redrawn using the software Revit. The 2D and 3D data produced enabled the precise architectural investigation and the identification of the unique architectural features of these garages. To gather more detailed data, the researcher went on field trips to Portsmouth, Bristol and Brighton & Hove, where the garages were photographed. Selected photographs are used in this thesis to visually present the case studies and deepen the understanding of their architectural characteristics which are rooted in the modern movement. Then the investigation focused on the application of the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA to the case studies. Before the investigation, field trips were used to identify the characteristics of each building and the urban context affecting architectural decisions. The phases, steps and tools used are specified within the guide that was developed. The planning phase of the guide identifies criterion which should be met to enable the up-cycling process from the planning perspective. Addressing this criterion can be done by following the two-step process. The first step aims to establish an understanding of the decision context. This is done through the planning policy analysis of selected cities, and the identification of the key development objectives as underlying policy statements. Having established the decision context, options to address objectives by exploiting planning opportunities and limitations (from interviews with experts, summarised in the first step of the guide) are explored from the perspective of the planning documentation. While the crucial goal of the limitations identified is to inform architects of the constraints that may arise in the initial stage of the proposal development, the results regarding the planning opportunities for the proposed adaptive reuse are further explored in the second step of the planning phase. This step verifies the primary data obtained through the planning framework that arose from the literature review in Chapter 4. Linking identified opportunities with these which are explored through the secondary research leads to the identification of the key planning drivers and motivations for the adaptive reuse of inner-city modern movement car parking structures for CEA. The results of the planning phase of the guide are relevant for architects when making design decisions for addressing the specific planning context in the initial stage of the architectural scenario development.

The architectural phase of the guide identifies criterion which should be met to develop a viable design scenario for the proposed up-cycling. Addressing this criterion should be done through the design thinking process by applying research by design in the two-step process. In the first step, architectural analysis is employed to establish an understanding of the opportunities and limitations represented by the architectural features of the selected modern movement garage. It is done using 2D and 3D plans drawn in Revit, which are specifically explored using Adobe Illustrator 2019. The units of analysis are the architectural opportunities and limitations identified through interviews with experts. This architectural exploration leads to the development of a matrix of visual findings, which are then interpreted and evaluated contextually from the perspective of the theoretical data gathered in Chapter 4 in the second step of the architectural phase. The decision context for this step is defined in the planning phase of the guide; specifically, the key drivers and motivations identified in the second step of the planning phase become objectives in the second step of the architectural phase. While this investigation is conducted as research by design, the critical investigation of the architectural approach that develops the viable initial design scenario is presented using graphic methods and descriptively summarised. The conceptualised design scenario for each case study is then analysed in Revit to generate quantitative data on the opportunities to implement CEA in the internal and external areas of the car parking structure.

The environmental phase of the guide uses data from the planning and architectural phases as the foundation for the investigation into the environmental criterion which arose from interviews with experts. The first step is the analysis of the theoretical data from Chapter 4 on opportunities and limitations for implementing resource-efficient technologies and alternative energy technology options in the process of up-cycling a specific modern movement garage for a CEA operation. The key environmental drivers and motivations defined in the planning phase are adapted as the objectives for this investigation. As this phase explores the architectural scale of the proposal development, the applicable objectives include improved water use efficiency, improved building energy efficiency, sustainable architecture, energy-efficient productive architecture and enhanced closed cycles. In the second step, the graphic findings from the final matrix developed in the architectural phase are linked to the findings from the first step of the environmental phase. Linking this step to the findings from the previous phases of the guide enables investigating the implementation potential of sustainable technologies, identified through the literature review, in the context of the architectural scenario developed for a specific car parking structure. Finally, the environmental scenario is developed for a specific case study.

2.10. Summary of Chapter 2

The chapter introduced the philosophical framework of the thesis, which indicates the role of research in innovative design problem solving, and the development of procedures for conceptualising new architectural typology. The typological approach to architecture was discussed and located within the framework of this thesis. Then, the chapter identified design thinking as the crucial strategy for design research focused on the development of innovative architectural typology, which requires the adaptation of experimental or even hybridised methodologies. Such a methodology requires involving interdisciplinary experts, who together contribute to solving the innovative architectural problem. The design research is introduced first as research for design, conducted through theoretical investigation, and second as research by design, done by the empirical exploration of strategically selected case studies. The guide for the analysis of the adaptive reuse potential of inner-city car parking structures for CEA is introduced as the main outcome of the theoretical investigation, and the foundation for the empirical analysis. Finally, research methods and data analysis techniques were discussed. The following chapter investigates the planning, architectural and environmental opportunities and limitations for the adaptive reuse of urban structures for CEA.

Chapter 3: Literature review

3.1. Role and development of the global food supply system

While people mostly perceive food as sustenance, it is more than that. It is an integral element of the socio-cultural and economic ecosystem in which we live.

The food system encompasses ecosystems and all activities required for the production, processing, transportation and consumption of food, including inputs needed and outputs generated by each of these activities. Within this system, value chains are composed of the full range of farms, enterprises and their value-adding activities, which produce agricultural raw materials and transform them into food products sold to final consumers and disposed of after use (FAO, 2018, p. 2).

The food system, also referred to as food value chain, was fundamentally reorganised owing to the geopolitical changes which ended colonialism and began to transform food production and cultivation patterns (Friedmann & McMichael, 1989; Jenkins, 2018). Due to the constant changes in food demand, and the growing role of the economy in the value chain, food production, food trade, and the scale of food-related operations significantly increased. Consequently, the global food system became multi-scaled and complex, which made it vulnerable to disruptions, including a growing human population, changing diets, climate change, limited natural resources, channelling productive agricultural land to urbanization, and environmental variability (Foley et al., 2011; Godfray et al., 2010). To monitor the efficiency of the global food system, identify gaps, and provide future recommendations for maintaining the system's resilience, global governing bodies were established, such as the Food and Agricultural Organisation of the United Nations (FAO). The work done by these organisations increased the awareness of the current state and role of the global food value chain, and revealed that to feed the world's growing population much more food needs to be produced than was being produced at that time. In the mid-1960s, these conclusions led to the increased research focus on maximising the productivity of the global food system. The advances in the understanding of plant growth were termed a *green revolution,* and contributed to the intensification of agricultural production through the development of modern or high-yielding crop varieties, improved application of fertilisers, herbicides and pesticides, and the enhancement of water management and rural infrastructure (Evenson & Gollin, 2003) (Fig. 22). As a result of the intensification process, over the period from 1961 to 2007, the land area under agricultural production expanded from 4.51 to 4.93 billion ha, which is only 11 percent (FAOSTAT, 2009), while in theory, 29 percent more food may be consumed by one person today compared with 1960 (The Royal Society of London, 2009). Achieving the primary goal of the green revolution prevents many people from suffering malnutrition and famine. However, this global improvement in food security, rooted in new knowledge in the field of agricultural science and technologies, has brought undesired social, economic and environmental impacts (Foley et al., 2011; Godfray et al., 2010; Jenkins, 2018). The literature review of these impacts on the global scale is presented in Appendix A.

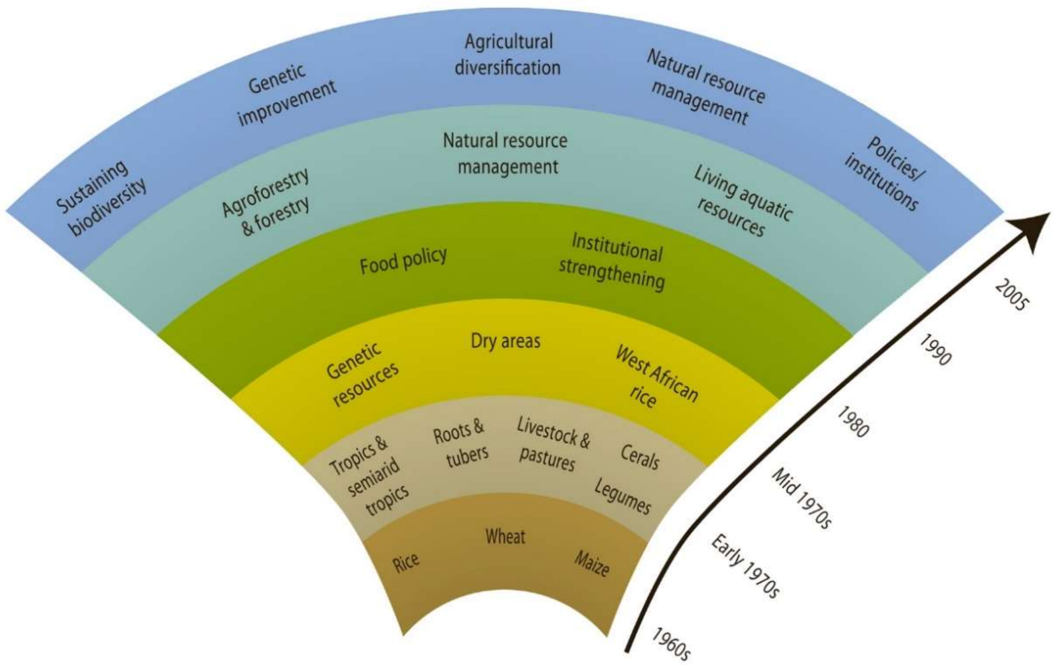


Figure 22: Pathway to the current conception of modern agriculture. Retrieved from: https://www.grida.no/resources/6334, copyright: IAASTD/Ketill Berger, UNEP/GRID-Arendal (accessed: 11.06.2019)

3.1.1. Food supply in the UK

The UK is an active participant in the global food system. In 2017, the value of food, feed and drink exports increased by 8.2 percent in comparison with 2016 and amounted to £22.0 billion. At the same time, the value of food, feed and drink imports increased by 7.1 percent to £46.2 billion. Trade includes various products, from raw agricultural commodities, lightly processed products such as cheese, meat and butter, flour and sugar, to highly processed foods. Fresh vegetables and fruit together represented the highest value foods for imports, totalling £6.2 billion (DEFRA, 2018). Sixty percent of export destinations in 2017 were to the countries in the European Union (EU) and 70 percent of imports were from the EU. These facts indicate that the UK is not only supportive of, but also reliant on, the global food system.

Between 2000 and 2016 global agricultural trade tripled in value (FAO, 2018a). The international agricultural organisations highlighted several positive economic aspects of this trend, for instance, the FAO (2018a) indicated the increasing participation of growing economies in the global agricultural market since 2000, and the acceleration of agricultural import growth compared to exports in developing countries. However, it was observed that food security of nations which import the majority of their food might be rapidly affected by global challenges and threats (Crivenau & Sperdea, 2014; Dalmeny, 2019; El Bilali, Callenius, Strassner, & Probst, 2018; FAO, 2018a; Miccoli, Finucci, & Murro, 2016; Schipanski et al., 2016). These objections opened a debate about food security, self-sufficiency and the resilience of the food supply chain in the UK. The Department for Environment Food and Rural Affairs (DEFRA, 2018) reported that in 2017 the UK was 60 percent food self-sufficient and over 75 percent self-sufficient in those foods, which can be produced within the country's borders. Although the British self-sufficiency ratio has been decreasing over the last thirty years (Fig. 23), in the context of historical standards, the value reported in 2017 is relatively high (Table. 3). Self-sufficiency, even if were possible, would not insulate the UK against threats and challenges to the domestic food supply and distribution system (DEFRA, 2008). It would make the UK more sensitive to political, technical, economic, demographic and environmental risks (Table 4). The dependence of agriculture on imported machinery and fertilisers, and the reliance of the food chain on various forms of domestic as well as imported energy, would compound the instability of the local food system. Therefore, the potential self-sufficiency of the UK is a complex and multidimensional topic and is not considered as an aim to be achieved (DEFRA, 2008).

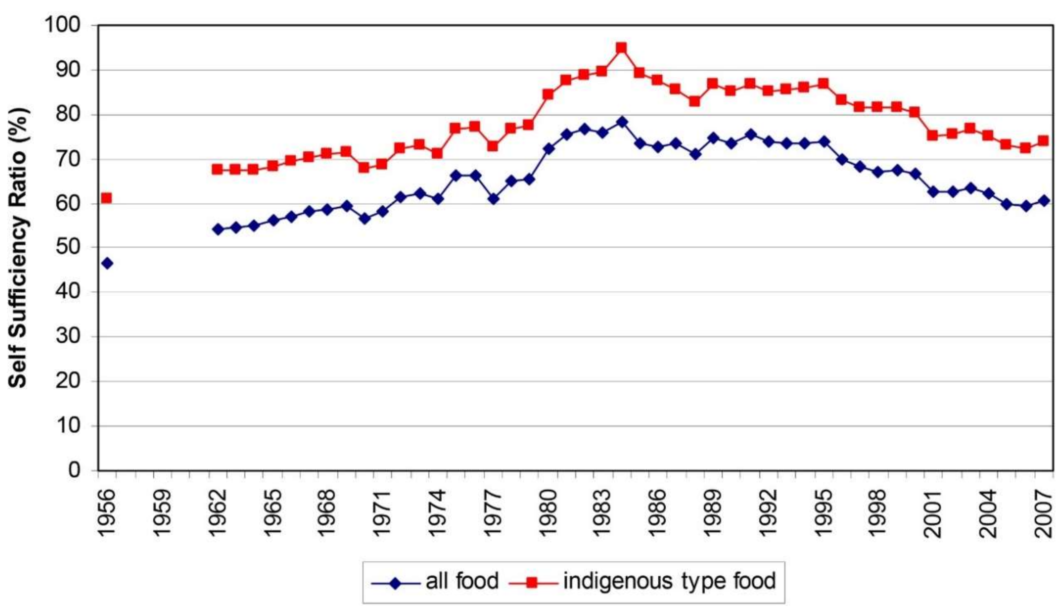


Figure 23: UK self-sufficiency 1956-2007. Source: DEFRA, 2008

Table 3: Indicative British self-sufficiency ratios over different periods. Source: DEFRA, 2008

Period	Self-sufficiency ratio
pre – 1750	around 100% (in temperate produce)
1750 – 1830s	around 90-100% except for poor harvests
1870s	around 60 %
1914	around 40%
1930s	30-40%
1950s	40-50%
1980s	60-70%
2000s	60%

Table 4: Threats and challenges to the UK`s food supply. Source: DEFRA, 2009

	Types of threats and challenges (illustrative)			
Scorecard themes	Political	Technical	Demographic & economic	Environmental
Global availability	Wars; Export restrictions; Bilateral land deals; Bio-fuel policies	Yield growth; Investment and skills	World population growth; Income growth	Floods, droughts; Plants/animal disease; Changing climate
Global resource sustainability	Wars; Institutional and policy failures	Farming practices	World population growth; Farming intensification	Water scarcities; Desertification; Soil erosion; Climate change; Ecosystems breakdown
UK availability and access	Trade embargoes; Breakdown in international trade; Breakdown in EU trade; EU regulations	Decline in non-renewable energy; Port closures	Importance of fruit and veg consumption and imports; Sharp decline in UK competitiveness	Animal disease; Coastal flooding of ports; Water scarcities; Bio-diversity risks
UK food chain resilience	Strikes/ protests; Regulation	Radioactive fallouts; IT corruption; Contingency planning; Just-in-time	Oil shocks; Absenteeism due to pandemic flu; Food chain concentration; Financial crises	Extreme weather events
Household affordability and access	Planning restrictions	Lack of transport	Poverty; Food inflation; Currency devaluations; Unemployment	Extreme weather events
Safety and confidence	Malicious activity; regulatory failures	Contamination	Increasing demand for complex processed products; Longer supply chains	Pests and diseases

2.1.1. Food security: the British Government's approach

The British Government's approach to supporting and improving the food security of the nation is based on five priority areas: (1) *global availability,* (2) *diversity of supply,* (3) *food chain resilience,* (4) *affordability and* (5) *safety and confidence* (DEFRA, 2008, p. 28).

The effectively functioning global market is seen as the primary pillar of food security. The UK not only actively participates in global trade, but also committed to an aid package aimed at reducing the food insecurity of the most vulnerable countries. For instance, at the request of the UK at the G8, it was decided to invest over $10 billion in supporting immediate humanitarian needs, increasing and enhancing agricultural productivity in developing countries over the longer term. Contributing to these goals is expected to keep stable and all-inclusive food prices, as disturbances in global production will result in a price increase, thereby affecting consumers in the UK (DEFRA, 2008). The effective functioning global market influences the second priority area: *maintaining the diversity of supply sources*. Relying on different trading partners as well as the domestic food supply is considered a strategy to minimise the potential negative impacts of disruptions on food security in the UK due to the spread of trade risks, the competitiveness of prices and the diversity of supply. The stability of the food system is enhanced through strategic decisions on trading partners, as too excessive a dependence on one country makes the supply too fragile to potential threats and challenges. Thus, in 2017, no single country contributed to more than 13 percent of UK food imports (DEFRA, 2008). Relying on imports from the EU is seen as a way further to reduce the risk, as Member States of the EU are considered as stable trading partners (DEFRA, 2008). The third priority area, *improving food chain resilience,* depends on the complex and sophisticated supply chain and infrastructure, primarily energy reliability, diversity of oil and gas imports, IGD retailer stock levels, cereal stock ratios, retailer concentration ratios, business continuity planning, and port capacity (DEFRA, 2008, 2009). The last two priority areas of the UK food system, *the affordability of nutritious food,* and *safety and public confidence,* are mainly enhanced through maintaining the first three priority areas. Further actions include launching food assurance schemes, such as Linking the Environment and Farming (LEFA), and providing food aid (DEFRA, 2008). Although the British Government is continuously working on the assumption of improvements in the five interdependent priority areas, availability, access and utilisation of food over time has not been reached, and social and environmental food-related issues are continually growing (Loopstra & Lalor, 2017; Wczasek, 2017).

3.1.2. Social impacts of the UK food system

Even though food price by calorie has significantly reduced over the last 60 years, the nutritional quality of food consumed in the UK has declined (Bristol Food Network, 2009). Consequently, the scale of diet-related health problems is increasing (Moreira et al., 2015; Statistic Team NHS Digital, 2018). In 2016, 26 percent of adult Britons were obese. In 2016/17, the prevalence of childhood obesity was 10 percent among children in reception year, and 20 percent in year 6 (Statistic Team NHS Digital, 2018). The future prognosis shows that this issue will further grow to affect 60 percent of males and 50 percent of females by 2050 (Butland et al., 2007). The leading cause of these predictions is the patterns of current food intake and activity behaviour, which show an increasing consumption of foods with a high energy density (Butland et al., 2007). Such products are mainly processed foods, often sold as ready-to-heat or ready-to-eat. Moubarac et al. (2013) revealed that in 2008/09 ready-to-consume food and drink products provided 58 percent of overall caloric intake in the UK. Although obesity is not exclusively a matter of social class, it was observed that the relative cheapness of processed foods is one of the main reasons behind their high consumption by low-income groups, for whom the affordability of fresh products is often reduced (Butland et al., 2007). Therefore, the affordability of fresh foods is seen as a strategic improvement area in the UK food system for countering health inequalities and tackling obesity.

Simultaneously, hunger, food insecurity and malnutrition affect the most vulnerable social groups, including the ageing population (Purdam, Esmail, & Garratt, 2019) and children (Arteaga et al., 2016; Garratt et al., 2016; UNICEF Office of Research, 2017). The Trussell Trust (2017) states that the emergence of food aid provision underpins the failure of the current approach to improving food security in the UK. In the past ten years, the number of food banks, where people can receive free emergency food assistance, has considerably increased. For instance, one of the largest national networks, The Trussell Trust Foodbank Network, has grown from 30 food banks working in 2009 to over 420 operating in 2017 (Loopstra & Lalor, 2017). The number of instances of emergency parcels being obtained through their Network has increased from about 61,500 in 2010/2011 to over 1.18 million in 2016/2017 (The Trussell Trust, 2017). This is associated with the change in policies on economic austerity (Dowler & Lambie-Mumford, 2015) in parallel with rising fuel and food prices (Lambie-Mumford & Dowler, 2015). Considering this evidence, it seems that the British Government’s actions to support and improve the food security of the nation are not having the desired effects. The numbers seeking charitable help and reporting a critical decline are growing, as maintaining five priority areas for enhancing food security is a multidimensional challenge, the outcome of which is affected by many potential problems that are already known (Table 4) but whose consequences are difficult to predict, and new threats may even arise in the future.

3.1.3. Environmental impacts of the UK food system

The increasing reliance of the UK on the global food supply chain is reflected in the rising adverse environmental impact that this has, both abroad and within the country. The UK food and feed supply are responsible for the increase in the total cropland footprint from 8900 Kha in 1987 to 10 922 Kha in 2008. In 1987 about 57 percent of this cropland footprint was located abroad, and in 2008 this value increased to about 67 percent. The most substantial increase in the UK cropland footprint is reported in South America (þ1437 Kha) and the Former Soviet Union (þ791 Kha). Argentina and Brazil are the countries which account for the largest share in the cropland footprint of the UK, both contributing about 9 percent to the total cropland footprint of the UK (De Ruiter et al., 2016). The distance between the UK and the cropland which supplies the country in food and feed puts the spotlight on food miles and their negative environmental impact. In 2010, food transport for UK consumers emitted 15,382 kgt of CO_2. The highest ecological impact per tonne is associated with the air freight of food, which accounted for 12 percent of total CO_2 emissions from the transport of food in 2010. At the same time, UK heavy goods vehicle food transport added the most to CO_2 emissions and accounted for 29 percent (DEFRA, 2012). These facts indicate the high environmental costs of the UK's reliance on the global food system and the intensive agricultural operations performed to feed its population (Cabinet Office, 2008; De Ruiter et al., 2016; DEFRA, 2016; Jenkins, 2018; Office for National Statistics, 2013).

The evidence presented supports the hypothesis that the adverse impacts of the current food system in the UK are not only associated with the global, but also with the domestic food supply. The food chain consists of many complex and multidimensional operations, which need modifications to become sustainable and resilient. Current literature indicates several strategies for bringing about such improvements, one of which is the shift to local food production, distribution and consumption (Blake, Mellor, & Crane, 2007; Kemp, Insch, Holdsworth, & Knight, 2010; Mohareb et al., 2017).

3.1.4. Enhancing the local food supply in the UK

Recognising the role of growing more food domestically and purchasing local products in preventing further ecological damage and improving the food security of the nation offers opportunities for implementing changes within the UK food industry, society and policy. With the main aim of achieving these goals, several organisations arose in the UK, for instance Sustainable Food Cities and the Bristol Food Network. By organising social campaigns, webinars, engaging with authorities and conducting research on the local food supply chain, these organisations contribute to the development of sustainable food systems and the consumption of sustainable food, which is defined as food that:

- *Preserves fossil-fuels and mitigates against climate change*
- *Protects people's health and the welfare of animals*
- *Stimulates and strengthens local economies*
- *Improves the local environment and enhances bio-diversity*
- *Creates social benefits, such as community spaces to enjoy healthy, affordable food*
- *Respects the rights of everyone involved in its production, both locally and globally*
- *Respects the right of all peoples to define their own food systems*

  (Bristol Food Network, 2009, p. 7-8).

Sustainable food is grown, produced and sold:

- *Locally, with minimal food miles by local enterprises that enrich and support the local community*
- *Naturally, without oil-intensive production methods, fertilisers, chemicals and packaging*
- *Fairly, in the absence of exploitation in its production, processing or retailing* (Bristol Food Network, 2009, p. 8).

The local food supply is a crucial element of the sustainable food chain, providing social, environmental and economic opportunities on the regional scale. Growing more food domestically, purchasing local products and reducing food-related waste is recognised as a strategy for preventing further ecological damage and adverse social impacts within the UK (Blake et al., 2007; Kemp et al., 2010; Mohareb et al., 2017). However, current studies highlight several challenges for local food production and consumption. These include agricultural land availability (Jenkins, 2018), diversity in the perception of *local* within food production (Blake et al., 2007; Ilbery & Kneafsey, 2000), consumers' choices, their knowledge on the role of purchasing local food in the global context (Blake et al., 2007; Kemp et al., 2010), their belief that local food must be expensive (Blake et al., 2007) and inherently exclusive (DuPuis & Goodman, 2005), the quality and safety of local food (Ilbery & Kneafsey, 2000) or prevailing power relations in the existing food supply chain that prioritise large international retailers (Holloway et al., 2007). In this context, the enhancement of a local and sustainable food chain becomes a complex goal. Contributing to this goal lies not only in increasing domestic food production and distribution, but also improving consumer awareness (Blake et al., 2007; DuPuis & Goodman, 2005; Kemp et al., 2010), informing and engaging local authorities (Bristol Food Network, 2009; Davis, 2018) as well as promoting local producers (Bristol Food Network, 2009; Holloway et al., 2007; Sustain, 2019).

According to Jenkins (2018), there are three strategies with the potential to increase domestic food cultivation. First, to continue and progress agricultural intensification to grow more food on already cultivated land, second, to allocate more land for agriculture and third, to develop urban agriculture in urban and peri-urban areas. While degraded ecosystem services, a range of resource peaks and the requirement to preserve land for natural habitats in the UK limits the possibility to implement the first and second strategies, it is necessary to investigate scenarios for implementing urban agriculture (e.g. Jenkins, 2018; Miccoli et al., 2016). Developing UF may enhance a local and sustainable food system as a secondary food source for future generations.

3.2. Urban agriculture as a local secondary food source

Expanding cities are resource-intensive systems, which will need 30 percent more food produced on less land, with fewer pesticides, less water and fewer materials (Lehmann, 2010a). UA is arising as a practice which directly corresponds to these concerns, contributing to daily food requirements and long-term, economic and environmental urban resilience by cultivating food close to consumers (Redwood, 2009). While UA is a global phenomenon, farming operations developing in cities are not homogeneous. The purpose and advantages of UA for producers, consumers and ecosystems differ in the global north and south (Thornton, 2013), owing to the complexity of factors and drivers impacting production and consumption in various geographical locations, including rates of population growth, cultural habits, consumption patterns, cultural habits or proportions of wealth spent on food (Tornaghi, 2014). Therefore, definitions of UA formulated for developed and developing countries vary as well (Appendix A). This dissertation is focused on UA practices located in the global north. Thus, the definition of UA is adapted from Sanyé-Mengual, (2015) based on findings and conclusions from Working group 1 of the COST Action *Urban Agriculture Europe* (Lorhberg & Timpe, 2012). The definition of UA in this dissertation is:

Urban agriculture are farming operations taking place in and around the city that beyond food production provides environmental services (soil, water and climate protection; resource efficiency; biodiversity), social services (social inclusion, education, health, leisure, cultural heritage) and supports local economies by a significant direct urban market orientation (Sanyé-Mengual, 2015, p. 11)

This definition presents a multifunctional role for UA (Lovell, 2010; Zasada, 2011), recognised as a contribution to sustainable urban development (Miccoli et al., 2016) (Fig.24). Enhancing food security is recognised as one of the benefits (Ackerman, 2012; Ackerman, Dahlgren, & Xu, 2013; Despommier, 2011; Gordon, 2016; Jenkins, 2018), though many researchers and decision makers prioritise social (Aerts et al., 2016; DiDomenica & Gordon, 2016; Guitart, Pickering, & Byrne, 2012; Lovell, 2010; Miccoli et al., 2016; Paxton, 2012), economic (Bristol Food Network, 2009; Despommier, 2011; Lehmann, 2010b; Miccoli et al., 2016; Murray, Skene, & Haynes, 2017) or environmental (Aerts et al., 2016; Delaide, Goddek, Gott, Soyeurt, & Jijakli, 2016; Ellingsen &

Despommier, 2008; Girardet, 2008; Specht et al., 2013) opportunities arising from the supportive relationship between UA practices and the urban environment. These multidimensional benefits of UF are often critical drivers for enabling the implementation of farming in an urban environment by local authorities (Davis, 2018).

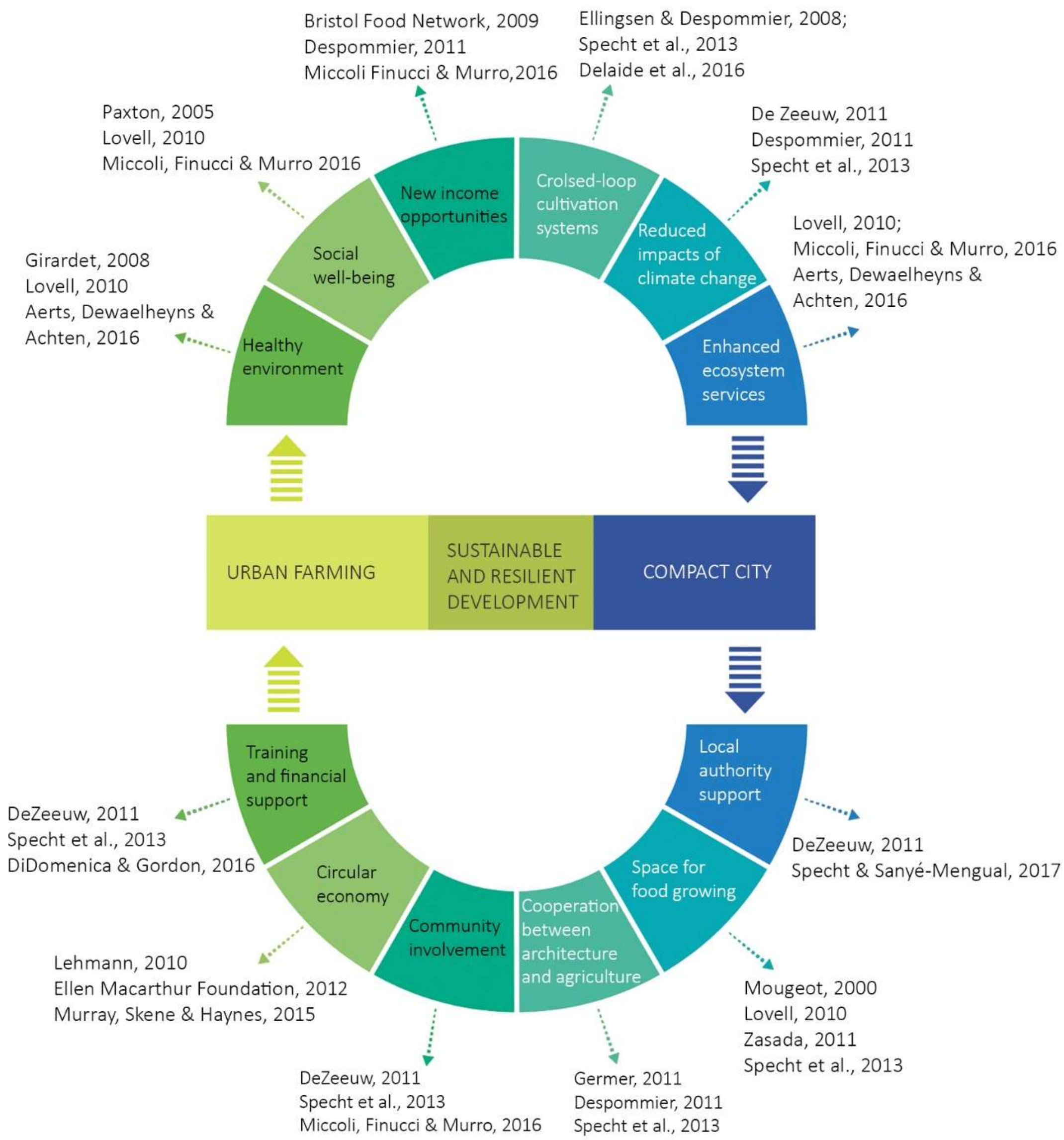


Figure 24: The relationship between urban farming and the urban environment, by Szopinska-Mularz

3.2.1. Challenges for urban agriculture posed by the urban environment

While increasing urban density and compactness are now seen as key drivers towards sustainable urban development (e.g. Lehmann, 2010b, 2017), the current narrative of UA raised concerns regarding challenges for the implementation of food growing practices in such cities. In a study investigating the role of UA in a framework of landscape multifunctionality, Lovell (2010) highlighted many competing land use needs and the high value of land as crucial limitations for implementing farming activities in cities. Likewise, Specht et al. (2013) recognised land availability and access in densely built-up areas as constraining factors for soil-based agriculture. Degraded ecosystem services are seen as further threats to traditional UA. When analysing the contribution of UF to environmental sustainability, Aerts et al. (2016) pointed out soil contamination and the concentration of heavy metals and other toxic compounds in the air as potential hazards for the quality of vegetables and fruits produced in urban areas. At the same time, peri-urban agriculture is challenged by phenomena contributing to urban sprawl. Zasada (2011) analysed the ongoing academic discussion on the multifunctionality of farming on urban fringes and revealed that the area used for agriculture is decreasing owing to competing demands for space. Recognising the development potential of peri-urban regions, investors offer strong financial encouragement to farmers to sell agricultural land, which leads to a high degree of land-use conversion and transition for urban purposes. Such a process often results in a chaotic composition of different land uses (Robinson, 2013; Zasada, 2011). In an investigation into land-use change in the *edgelands* of London, Gant, Robinson, & Fazal (2011) indicated the adverse outcomes of such land speculation, which include collective land tenure by producers, and expanding shares of non-agricultural owners. The main reason for these challenges posed by continuously evolving cities is a lack of policies which enhance existing and support new farming practices in urban areas (Ackerman, 2012; Cerón-Palma et al., 2012; Thomaier et al., 2014). Planning officers perceive UA as competing for limited space with the various land uses prioritised due to higher social or economic benefits, for instance, affordable housing or quality office space (e.g. Campbell, 2016; Gant et al., 2011; Rich, Rich, & Dizyee, 2018). Considering all of this evidence, it seems that the implementation of UA is a complex and complicated process, which may be only done as an interim solution before more profitable investment opportunity will arise, or funding for prioritised land-use will be obtained. However, much of the current literature highlights the potential of low-space or no-space UA technologies as an alternative for traditional soil-based farming practices (e.g. Ackerman, 2012; Caplow, 2010; Cerón-Palma, Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall, 2012; Despommier, 2011b; Germer et al., 2011; Gould & Caplow, 2012; Jenkins, 2018; Nelkin & Caplow, 2008; Specht et al., 2013; Thomaier et al., 2014; Ting, Lin, & Davidson, 2016). A significant area of interest within these specific UA operations focuses on building-based farming, where the adaptive reuse of urban structures for agriculture is recognised as a practice which minimises the environmental and economic costs related to the demolition of the existing structure and the development of a new structure for food production (Despommier, 2011; Sanyé-Mengual, Cerón-Palma, et al., 2015; Specht et al., 2013).

3.2.2. Adaptive reuse of buildings for urban agriculture

Adaptive reuse, also known as repurposing or up-cycling (Lehmann, 2016b) refers to:

The process of reusing an old existing building or site for a purpose other than which it was built or designed for (Lehmann, 2016, p. 56).

During the past twenty years, the shift to the reuse and adaptation of buildings has become an increasing trend (e.g. Bon & Hutchinson, 2010; Boschmann & Gabriel, 2013; Bueren & Jong, 2016; Bullen & Love, 2010a, 2010b; Ellison, Sayce, & Smith, 2007; Gallant & Blickle, 2005; Lehmann, 2016a; Petersdorff, Boermans, & Harnisch, 2006). Through adaptive reuse, unoccupied, derelict buildings can become suitable for various types of uses. One of these uses is UA. Several such retrofits already exist as an answer to the challenges to traditional in-soil farming posed by the urban environment. Building-based UA concepts, which consider repurposing existing urban structures, are building-integrated agriculture (BIA) (Caplow & Nelkin, 2007), Zero-acreage farming (ZFarming) (Specht et al., 2013) and vertical farming (VF) (Despommier, 2011a).

Building-integrated agriculture (BIA)

In 2009, Caplow introduced the term building-integrated agriculture (BIA) as:

A new approach to production based on the idea of locating high-performance hydroponic farming systems on and in buildings that use renewable, local sources of energy and water (Caplow, 2010, p. 55)

In an investigation into up-cycling opportunities for BIA in New York, Gould & Caplow (2012) demonstrated that repurposing existing rooftop real estate for UA has the potential to provide 100 percent of the fresh vegetables required to feed the city's population. Soilless farming culture, more specifically hydroponics, is seen as the technique which should be applied in BIA, owing to benefits for food production and the light weight of the construction, crucial when retrofitting buildings without the need to reinforce the structure, which is associated with additional initial costs. The authors recommend retrofitting some areas of mixed-use buildings for farming and developing synergies between various uses, including waste heat and CO_2 exchange. These exchanges of urban resources, supported by water-saving and recycling systems, energy-saving systems and alternative energy technology options, are recognised as crucial for minimising the negative impact of BIA operations on the built environment (Nelkin & Caplow, 2008).

The limitations identified for building commercially and environmentally viable BIA include planning aspects: exploring appropriate sites and interpreting building, zoning and permitting regulations, as well as technical barriers associated with creating synergies between existing structures and farming activities (Caplow, 2010; Caplow & Nelkin, 2007; Germer et al., 2011; Gould & Caplow, 2012). Gould & Caplow (2012) indicated the need to develop innovative solutions which will advance the concept at the environmental level, for instance, for capturing waste heat, saving energy and implementing more sustainable lighting sources. The research, although giving many recommendations for the adaptive reuse process, fails to address specific design issues and challenges arising when up-cycling buildings for BIA. For instance, a very general conclusion stating that when implementing a lightweight hydroponic greenhouse, the accommodating building usually does not require any significant structural reinforcement, is not based on any calculations. Therefore, several new limitations may arise when the attempt is made to design and construct a BIA operation as the adaptive reuse of an urban structure.

Zero-acreage Farming (ZFarming)

Specht et al. (2013) defined Zero-acreage Farming (ZFarming) as:

All types of urban agriculture characterized by the non-use of farmland or open space, thereby differentiating building-related forms of urban agriculture from those in parks, gardens, urban wastelands, and so on (Specht et al., 2013, p. 35).

Such forms of cultivation include rooftop greenhouses, rooftop farms, edible green walls and indoor farms as well as more technologically advanced techniques such as indoor vertical soilless farming and vertical greenhouses (Specht et al., 2013). The core idea for ZFarming is to integrate agricultural practices into existing buildings, which is seen as a strategy to use and recycle resources derived from the symbiotic relationship between agriculture and architecture, developed as a closed-loop resource system. The possible exchange of resources (e.g., organic waste, waste heat, industrial or residential wastewater) between technologically advanced farming operations and buildings arises as a practice that may mitigate the harmful impact of urban development and reduce the environmental burdens related to the high resource-demand of soilless farming activities (e.g. energy for heating or cooling the farm) (Specht et al., 2015).

In a comprehensive study, Thomaier et al. (2014) analysed and assessed existing ZFarming operations through a qualitative approach. The research identified 73 ZFarming projects: 44 in North America, 19 in Europe, 15 in Asia and one in Australia. However, this analysis does not provide information on how many of these practices utilised existing buildings. While Specht et al. (2013) highlighted that the fundamental idea behind ZFarming is retrofitting existing buildings, the assumption can be made that social, economic and environmental benefits derived from all of the agricultural operations reported by Thomaier et al. (2014) are associated with up-cycling existing building stock. The research does not provide any data on specific design aspects of repurposing buildings for ZFarming.

Vertical Farming (VF)

Despommier (2010, 2011) established the concept of Vertical Farming as:

Farming inside tall buildings within the cityscape (Despommier, 2011, p. 233)

The VF concept arose in response to the rooftop garden model, where the total productive area on the urban scale offers a minimal contribution to the self-sufficiency of the city (Despommier, 2010). The author of the VF proposal highlighted the possibility for multiple vertically hydroponic growing systems in the controlled environment created inside tall buildings, both existing and newly built. However, retrofitting existing building stock for VF is associated with limitations, which may negatively affect productivity. The crucial challenge includes the adaptation of existing material and technologies to create a viable food production system, including maximising access to natural light, increasing the productive area or implementing alternative energy technology options, water and energy-saving systems. Therefore, Despommier (2010) considers up-cycling urban structures for VF as *a logical next step towards constructing a free-standing vertical farm (…)* (Despommier, 2010, p. 236).

The VF concept would appear to be over-ambitious in its claims, as the research up to now has been descriptive in nature and has not been conceptualised in any specific urban context. The published studies are limited to indicating and summarising the benefits of VF and proposing several technologies for VF. At the same time, no attempt has been made to explore the many and complex design challenges which may limit the implementation of such UA installations. In his analysis on the VF concept through a survey of the existing literature exploring the topic, Al-Chalabi (2015) argues that this UA concept has the potential to be developed and make an actual contribution to the urban food supply in the right circumstances. The author claims that VF *is a concept that is in its technical infancy but does hold promise for future cities* (Al-Chalabi, 2015, p. 77). However, much more research is needed to establish a VF model which could be built in cities. The study would have been more relevant if the author had considered repurposing buildings for VF first, instead of focusing on new build vertical towers associated with high initial costs.

Taken together, these studies support the notion that, in the context of the current global food system, the role of building-integrated UA as a secondary food source will grow in future. Existing buildings are seen as a resource that, when up-cycled, can provide a space within a dense urban environment for UF. However, the design of building-integrated food systems is associated with numerous uncertainties. The main obstacle for the architect, the principal agent in the design of such productive systems, is the fact that not much detailed and transferable data relevant for the design of viable building-based UA can be identified (Jenkins, 2018). Existing practices were constructed through trial and error, and did not provide communicable knowledge. It is challenging to explore, critique and progress the design and performance of any known concept. Therefore, it is essential to analyse and document the current state of knowledge and generate new data on the planning, architectural and environmental opportunities and limitations which should be considered by the architect in order to conceptualise the adaptive reuse potential of an urban structure for UA.

3.2.3. Controlled environment agriculture

The building-based UA concepts presented highlighted the crucial role of soilless agriculture, carried out in a controlled environment created within or upon existing structures, in maximising the amount and nutritional quality of crop yields as well as reducing the environmental impacts associated with growing food in the urban environment (Caplow, 2010; Caplow & Nelkin, 2007; Despommier, 2010, 2011; Ellingsen & Despommier, 2008; Nelkin & Caplow, 2008; Specht et al., 2013; Thomaier et al., 2014). Controlled environment agriculture is:

A technology for plant production in environmentally-controlled structures such as high tunnels, greenhouses, growth chambers, or indoor vertical farming (…). The aim of CEA is to provide protection from pests and diseases and maintain growing conditions for optimising plant growth and quality (Niu & Masabni, 2018, p. 1).

Food cultivation techniques utilised in CEA are soilless cultures, which are defined as:

Any method of growing plants without the use of soil as a rooting medium, in which the inorganic nutrients absorbed by the roots are supplied via the irrigation water (Savvas, Gianquinto, Tuzel, & Gruda, 2013, p. 303).

In soilless culture systems, the crop roots are grown either directly in a nutrient solution, or porous substrates also named rooting media. In plant cultivation terminology, the rooting media are considered as *all those solid materials, other than soil, which alone or in mixtures can guarantee better conditions than agricultural soil (for one or more aspects)* (Gruda, Prasad, & Maher 2006, p. 1644). During the cultivation cycle, fertilisers with the appropriate concentration of nutrients are dissolved in the irrigation water and supplied to the plant as a nutrient solution. This process allows for controlling the quantities of water, dissolved oxygen and mineral salts. To maximise yield and quality, the amount of these components are carefully balanced according to the requirements of specific plants (El-Kazzaz & El-Kazzaz, 2017).

A considerable amount of literature has been published on building-based CEA as it is seen as the food production system with the highest productivity potential for future cities (e.g. Benis & Ferrão, 2018; Despommier, 2010; Germer et al., 2011; Nelkin & Caplow, 2008; Ting et al., 2016). El-Kazzaz & El-Kazzaz (2017) highlighted high productivity and the nutritious quality of vegetables and fruits, which can be produced all year round in a controlled environment, as crucial benefits of CEA. These arise from the control of the different parameters of the internal environment, including temperature, CO_2 and humidity levels, ventilation, pH, light intensity and the plant's genetic make-up, at the levels required by individual plant species. Through precise control of the internal environment of such systems, and the integration of sustainable technologies for resource-saving and generation, the reliance upon, and use of, urban resources can be significantly minimised (Alshrouf, 2017; Jenkins, 2018; Nelkin & Caplow, 2008; Putra & Yuliando, 2015; Togawa et al., 2014). When compared to in-soil farming techniques, CEA allows for minimising the use of pesticides and herbicides (Jenkins, 2018; Nelkin & Caplow, 2008), reducing space requirements for food production (Tsitsimpelis, Wolfenden, & Taylor, 2016), developing technical synergies between agriculture and architecture (Nelkin & Caplow, 2008; Thomaier et al., 2014; Ting et al., 2016; Togawa et al., 2014), and minimising the risk of plant diseases (Orozco, Rico-Romero, & Escartin, 2008; Savvas, 2002; Savvas et al., 2013). According to Lehmann, (2010a) and Gould & Caplow (2012), CEA reduces and slows the loss of rural agricultural land to large-scale commercial farming. While agricultural production needs to expand in the nearest future to meet the requirements of the growing population, CEA is recognised as a cultivation technique which has the potential to become a significant secondary food source in cities (Jenkins, 2018).

3.2.4. Soilless growing techniques for controlled environment agriculture

Soilless culture systems include hydro agriculture (Hydroponics), aerobic agriculture (Aeroponics) and aqua agriculture (Aquaponics). These farming techniques are divided into subcategories, each with more advanced solutions. As this research focuses on the up-cycling potential of buildings for CEA, only the main categories are discussed in this section. The comparison of the advantages and disadvantages of these systems are presented in Table 5.

Hydroponics

Hydro agriculture is a water-based growing system, where an inert medium, such as coconut fibre or Rockwool, is used to accommodate the roots and distribute supplements. The essential nutrients for plant growth are added either automatically or manually into a water system. Hydroponic systems first pump water enriched with nutrients from the reservoir to plants where the nutrients are absorbed by the roots. Water falls back to the reservoir and is pumped around the system again. During this continual process, the nutrients within the system gradually deplete and need to be added again regularly to ensure continued growth (Jenkins, 2018). Five different types of hydroponic systems are presented in Appendix A.

Aquaponics

Aqua agriculture is a combination of hydroponics and a system where aquatic animals, such as fish, are grown in tanks. These two systems create a highly-resource efficient system. The excretions produced by aquatic animals accumulate in the water, and the water is passed to a biofilter, where nitrification bacteria transfer ammonia into nitrates. As the next step, these substances are moved through the water to the hydroponic installation and used by the cultivated plants as nutrients. The filtered water returns to the aquaculture tank (El-Kazzaz & El-Kazzaz, 2017). In a closed-loop system, waste from plants is decomposed to become food for worms, which then nourish the aquatic animals (Ackerman, 2012).

Aeroponics

The aeroponic system is considered the high-tech type of hydroponics. Sealed root chambers are used as a reservoir for the nutrient solution. The plants are located above the reservoir cover and their roots hang in mid-air above the reservoir. Every few minutes, a pump spreads the nutrient solution from the reservoir to the space around the roots (El-Kazzaz & El-Kazzaz, 2017). Vegetables are cultivated in holes in installations made of expanded polystyrene or similar material. The roots are suspended in the spraying box located beneath the panel. To inhibit algal growth, the specific environment is created inside the box, in which parameters such as saturation humidity are controlled. To keep roots moist and nourished, the pump sprays the nutrient solution every 2-3 minutes (El-Kazzaz & El-Kazzaz, 2017).

Table 5: The comparison of advantages and disadvantages of hydroponics, aquaponics and aeroponics. Sources: Alshrouf, 2017; Cardoso, Martinez, da Silva, Milagres, & Barbosa, 2018; Jenkins, 2018; Kloas et al., 2015; Niu & Masabni, 2018; Poulet et al., 2014; Rouphael, Kyriacou, Petropoulos, De Pascale, & Colla, 2018; Saha, Monroe, & Day, 2016; Savvas, 2002

System	Advantages	Disadvantages
Hydroponics	Lightweight; Low maintenance; High water and nutrient use efficiency in comparison with soil-based agriculture; Control of the quality, health and quantity of plants	Periodic intervention required; Reliance on mined minerals; Possibility to pass water-based disease to plants through the nutrient solution; High initial costs
Aquaponics	Creation of an ecosystem; High water and nutrient use efficiency in comparison with soil-based agriculture; Self-regulation; Fish harvesting as a by-product; Minimal need for mined minerals; Organic food production;	High weight of fish tanks and filtration units; Periodic deep cleaning; High initial costs

	Integration with waste streams of the city	
Aeroponics	Lightweight; Low energy requirements; High nutrient absorption; High water and nutrient use efficiency in comparison with soil-based agriculture; Control of the quality, health and quantity of plants	Complexity of construction; Complexity of equipment; High initial costs; Constant maintenance required for the control of pH and nutrient density ratios

In his dissertation on technical food systems, Jenkins (2018) analysed the implementation potential of soilless farming techniques within or upon buildings, based on a case study exploration of existing building-integrated CEA practices. Taking account the weight of the system and the benefits for plant cultivation arising from the placement of growing units in a specific location in or on the urban structure, the author provided a summary that is crucial for architectural considerations on the up-cycling potential of existing buildings for CEA. The results of the analysis are presented in Table 6.

Table 6: The analysis of potential locations of hydroponics, aquaponics and aeroponics within and upon buildings. Source: Jenkins, 2018

System	Location	Reason
Hydroponics	Basement; Ground level; Intermediate floor; Rooftop	Light weight of the system; Sunlight availability
Aquaponics	Basement; Ground level	Heavy weight of fish tanks and filtration unit;
Aeroponics	Basement; Ground level; Intermediate floor; Rooftop	Light weight of the system; Sunlight availability

3.2.5. Selection of a soilless growing technique for this thesis

The evidence reviewed on the advantages and limitation of soilless cultivation techniques and their possible locations within and upon existing buildings highlights hydroponics as the system with a high potential for quality crop growing, resource use efficiency and flexibility in making design decisions regarding the placement of the technology. Thus, the hydroponic system was chosen for this research. Although aquaponics has the stronger potential for environmental benefits, derived from the synergy between aquatic animals and cultivated plants, as well as the possibility for integration with waste streams of the city (Jenkins, 2018), the implementation of fish tanks and filtration units may be restricted to the basement and ground level, due to the structural limitations of the accommodating building. When a building is derelict, the idea to repurpose it with heavy fish tanks and filtration units could entail significant structural and architectural modifications, which generate the high initial costs that are perceived as a substantial constraint for building-based CEA (Jenkins, 2018; Lehmann, 2016b). While the literature analysed shows that aeroponics can be potentially installed on any level of the building, the complexity of construction and equipment needed for food production limits its implementation (Alshrouf, 2017; Jenkins, 2018). Thus, the manageability of hydroponics and the significant weight savings compared to other systems are considered the benefits that enable exploring various implementation opportunities and limitations within and upon urban structures (Cerón-Palma et al., 2012; Sanyé-Mengual, Cerón-Palma, et al., 2015). These aspects are crucial for investigating the initial adaptive reuse potential of modern movement garages for CEA from the architect's perspective as they allow the development of design scenarios arising from a comprehensive analysis of the building. Moreover, hydroponics is a base for the aquaponic system and a multitude of subsystems. Therefore, this investigation can create an architectural foundation, which can be modified or expanded by elements of more complex soilless growing techniques.

3.3. Inner-city modern movement car parking structures: adaptive reuse considerations

3.3.1. Traffic-related issues in urban areas

Increases in private car use in developed countries have compounded traffic-related problems in urban areas. Many cities declare that they have no more capacity to absorb the steadily increasing traffic caused by private cars, and are making every effort to reduce traffic congestion (Gössling, 2013; Ison & Rye, 2008; Marshall & Banister, 2000; Meyer, 1999; van Wee, Maat, & de Bont, 2012). With the growing number of cars, the risk of accidents increases and the perception of safety in areas of traffic decreases (Gössling, 2013). For instance in 2015, cars were responsible for 67 percent of collisions involving pedestrians in London (Transport for London, 2015). Restricting private car use is recognised as one solution for reducing road user risk (Gössling, 2013; Pratt et al., 2000) as well as adverse health consequences for urban dwellers caused by air pollution arising from traffic congestion (André, Carteret, Pasquier, & Liu, 2017; Gössling, 2013; Lehmann, 2017; Pasquier & André, 2017). It has been estimated that in 2013, 25 percent of CO_2 in the EU was emitted by urban transport (European Environment Agency, 2013). Owing to a high number of frequent short distance journeys, emissions per kilometre from vehicle use is higher in cities compared to longer trips outside urban areas (European Environment Agency, 2012). Furthermore, transport actively contributes to the depletion of already scarce resources (Marshall & Banister, 2000). While the global number of energy-dependent vehicles is predicted to surpass 2 billion by 2030 (Sperling & Gordon, 2009), the foreseen shortage of fossil fuel will pose a challenge in the transport sector, and contribute to the revision of personal mobility and parking patterns in cities (Aftabuzzaman & Mazloumi, 2011; Santucci, Pieve, & Pierini, 2016).

3.3.2. Strategies for reducing private car use in sustainable cities

In the context of increasing traffic-related issues and the forecast shortage of fossil fuels, urban areas are implementing strategies aimed at reducing private car use and developing sustainable mobility. Previous research has established that there are two ways to contribute to this goal. First, by implementing urban policies and land use planning focused on reducing demand for motorised transport and improving connectivity between urban functions (Gössling, 2013; Inturri, Ignaccolo, Le Pira, Caprì, & Giuffrida, 2017; Meyer, 1999; van Geet, Lenferink, Arts, & Leendertse, 2019; van Wee et al., 2012). Second, by shifting to innovative transport modes (Aftabuzzaman & Mazloumi, 2011; Brendel, Lichtenberg, Brauer, Nastjuk, & Kolbe, 2018; Santucci et al., 2016; van Wee et al., 2012).

Several methods have been developed to deliver the first strategy through planning and policy implementation. For instance, transport demand management is one of these tools, aimed at changing travel behaviour (Ison & Rye, 2008). Transport demand management is defined as *any action or set of actions aimed at influencing people's travel behavior in such a way that alternative mobility options are presented and/or congestion is reduced* (Meyer, 1999, p. 576). To achieve these goals, transport demand management implements measures, including road user charging, fuel tax, public transport subsidisation or park and ride facilities.

Another urban planning concept widely discussed in the current literature is Transit-Oriented Development (TOD) (Belzer & Autler, 2002; Calthrope Association, 2011; Taki & Maatouk, 2018). The contribution of TODs to traffic-related issues in cities is emphasised as follows:

the location, mix, and configuration of land uses in TODs are designed to encourage convenient alternatives to the auto, to provide a model of efficient land utilization, to better serve the needs of (…) diverse households, and to create more identifiable, livable communities (Calthrope Association, 2011, p. 2)

In their discussion paper, Belzer & Autler (2002) highlighted decreased traffic congestion, increased walkability, positive health outcomes, access to public transportation, reduction of petrol consumption and accessibility of services and public spaces as crucial benefits of TODs. The report on existing TODs in the US indicated up to a 42 percent reduction of private car ownership (Brownstein et al., 2008). In this context, land use planning makes a crucial contribution to a decrease in motorised mobility in cities.

Further opportunities for minimising traffic-related issues are recognised by restricting car use in some urban regions, as well as in specific periods or on specific days. While walking is still considered a minor mode of travel (Litman, 2011), most local authorities ban car use only in those urban districts, where pedestrianisation may significantly contribute to the reduction of traffic-related issues and bring social improvements, for instance, evoking new community activities (Nieuwenhuijsen & Khreis, 2016). Cities such as Brussels, Copenhagen, Dublin, Milan, Paris, Bogota or Chengdu use different measures to reduce motorised traffic, including announcing car-free days, increasing public transport provision, investing in pedestrianisation and cycling infrastructure and restricting parking spaces. In 2014, Hamburg announced the intention to become the first private car-free city by 2034. Oslo followed that claim in 2015 and declared the implementation of a policy aimed at a car-free centre by the end of 2019. Madrid intends to have a pedestrianised city centre by 2020 (Nieuwenhuijsen & Khreis, 2016). In their research on car-free cities, Nieuwenhuijsen & Khreis (2016) used a conceptual framework for linking urban and transport planning, environmental exposure, health and physical activity. They revealed that becoming a car-free city is not possible in the nearest future because of the low acceptance of such a change in people's behaviour, concerns about the reduction in retail sales, and car lobbying. However, the positive effects of the pedestrianisation of individual urban districts, especially inner-city and historical centres, have already been observed. For instance, in the report *The pedestrian pound. The Business Case for Better Streets and Places,* Lawor (2014) identified improved actual business performance, urban regeneration (e.g. rental income, new business and employment opportunities) and business diversity as the key advantages of pedestrianisation for economic sustainability. Such benefits are strong arguments for banning or significantly reducing private car use in central urban areas.

Opportunities arising from the shift to alternative transport modes are seen in investments in self-driving vehicles. Connected Autonomous vehicles and fully-autonomous vehicles are expected to reshape transportation patterns in cities. When substituting the human driver for innovative communication and sensing technology, such vehicles could reduce crashes and fatalities (Fagnant & Kockelman, 2018; Hashimoto, Gu, Hsu, Iryo-Asano, & Kamijo, 2016) as well as improving accessibility levels in many urban districts (Milakis, Van Arem, & Van Wee, 2017). Autonomous vehicles may be targeted directly towards specific travel needs, thereby minimising the negative travel-related impacts on energy use, land use, traffic congestion and public health (Chan, 2017; Crayton & Meier, 2017; Schoettle & Sivak, 2015; Zhang & Guhathakurta, 2017).

3.3.3. Car parking in inner-city areas

The evidence presented suggests not only a significant reduction in private car travel in future cities, but also a drawdown in parking space provision. These two factors are interdependent. In their study on the impact of off-street parking on the vehicle, miles travelled, car ownership and related carbon emissions, Weinberger, Seaman, & Johnson (2010) revealed that parking supply affects private trip demand by changing the cost structure linked to mode choice decisions. Off-street parking availability influences levels of car ownership by modifying the cost of this ownership. These facts suggest that parking management is a crucial tool for reducing traffic-related issues in urban districts.

Strategic parking management delivered by urban planning and policy is vital for modifying private car use in the inner-city. Such an approach is reflected in transport demand management, which employs parking charges and controls, as well as providing park and ride facilities on the urban fringes (Ison, Mulley, & Shaw, 2014; Meyer, 1999). Parking-related issues are also addressed in TODs, where removing parking from housing costs is recognised as a crucial contribution to more affordable housing options (Belzer & Autler, 2002). Moreover, a reduction in parking needs in the inner-city is associated with the introduction of self-driving vehicles. The International Transport Forum conducted case study-based research to analyse the impact of the operation of shared autonomous vehicles on urban traffic in Lisbon, Portugal. In the case of the most favourable scenario, which assumes the development of shared self-driving vehicles schemes together with high-capacity public transport, both off-street and on-street parking demand may be reduced within the city by 90 percent (International Transport Forum, 2015). In a study which set out to determine how much parking will be needed and where, if shared autonomous vehicles were to operate within the city of Atlanta, Zhang & Guhathakurta (2017) examined fee-paying and free-parking scenarios. The research adopted the Lisbon simulation model and revealed that in both scenarios, parking land might be reduced by about 4.5 percent once shared self-driving cars make up 5 percent of travel within the city. It was demonstrated that the use of each shared autonomous vehicle would reduce parking demand by at least 20 parking spaces on the city scale. Relocating parking from the inner-city, especially central business districts, is seen as the primary outcome of the introduction of shared self-driving cars.

The evidence presented suggests on-street, as well as off-street parking needs are declining, and this trend will continue in the future. Lower parking demand in central districts increases the availability of space as a desired and valuable resource in high-density urban environments (Nieuwenhuijsen & Khreis, 2016). While ideas for new development on disused parking lots in the inner-city are already presented in policy and research, the question about the alternative use for modern movement car parking structures is just beginning to arise.

3.3.4. Modern movement multi-storey car parking structures

Multi-storey car parking structures are easy to identify within the urban environment. Built for a practical reason, to park a car, they present a quality which arises from the structure, materials used and the light transmitted to the interior. In his book on the architecture of parking, Henley (2007) highlighted the radical change in architecture and urban landscape triggered by the introduction of multi-storey car parking structures as an architectural form that arose in the modern movement era. The earliest examples were built at the beginning of the twentieth century as concrete structures, for instance Garage Ponthieu Automobiles in Paris designed by Auguste Perret and built in 1905, or Automobile Club garage by Marshall & Fox built in 1907. In Europe, a substantial increase in car ownership was observed after World War II, when the devastation caused by wartime bombing brought about new urban regeneration strategies focused on motorised mobility, including multi-storey car-parking structures. In the UK, the Buchanan Report published in 1963 forecast a new urban order, where roads and car parks would become permanent elements of the urban landscape owing to the increased use of private vehicles for everyday travel (Gunn, 2011). Henley (2007) noted that from 1950, multi-storey garages were integrated into the built environment of numerous cities around the world, either as single-function structures or as a part of mixed-use development. The progress in construction knowledge and functional design focused on the circulation system, ramp design and parking layouts enabled the efficient design of these garages, where cars can be parked quickly and efficiently. The primary material used for the interior and the exterior was concrete, due to its plasticity, which offered numerous opportunities for shaping the structure. Using concrete led to the development of functionally and aesthetically autonomous megastructures where the surrounding urban fabric rarely informed the design. Since the early 1970s, a change in direction due to urban regeneration strategies and historic conservation led to the negative aesthetic and social perception of multi-storey car parks. Although these structures were still needed, their presence within city centres and historical areas was no longer welcome. These views were supported by the fact that traffic-related issues arose within urban areas and caused a need for developing alternative parking solution. By the end of the 1980s, park and ride facilities were located on the urban fringes and the investment was made in public transport. While some concrete garages were built later, they were mainly located outside city centres, often in business districts or as an element of housing or shopping centre developments (Henley, 2007). As current trends in car ownership indicate a decline in demand for parking in the inner-city, the future of existing car parking structures, seen as a relic of the modern movement era, has to be carefully considered.

3.3.5. Future scenarios for inner-city modern movement car parking structures

In his book on the architecture of parking, Henley (2007) identified two scenarios for the future of modern movement garages. The first scenario is to retain such structures and repurpose them with an alternative function. Several multi-storey car parks have already been proposed for conversion to other uses, for instance the Daimer Car Hire Garage (1931) and the Bluebird garage (1924) in London were converted to offices. The second scenario is to demolish a garage and replace it with new development, for instance Trinity Square Car Park built in 1967 in Gateshead was demolished in 2010 and the space was redeveloped as a commercial building. There may be good reasons for both scenarios.

Buildings are demolished when they no longer have value. This value is usually set by the market. As land in central areas of high-density cities is scarce, demolition and new development are often preferable as the strategy for achieving a quality architecture of specific function in high-demand associated with substantial market value (Kohler & Yang, 2007). Usually, if a structure becomes redundant, the decision on its future should be analysed from a life cycle perspective (Lehmann, 2016a, 2016b). However, eighty-one in-depth interviews with stakeholders, including architects, planners, developers, building managers and property consultants conducted by Bullen & Love (2010) revealed that assessing and comparing the social, environmental and economic performance of an existing structure and a new one is difficult, due to the significant differences in space and technological solutions. From the stakeholders' perspective, demolition and new construction are considered a more straightforward solution, directly targeted at environmental sustainability and market demand for modern spaces. The decision on demolition is often based on incomplete data gathered for the value assessment, which leads to the decision to demolish a derelict structure (Bullen & Love, 2010; Kohler & Yang, 2007; Shipley, Utz, & Parsons, 2006).

When considering the future of a building, project complexity is indicated as a crucial constraint for its adaptive reuse (Conejos, Langston, Chan, & Chew, 2016; Ellison et al., 2007; Kurul, 2007). In many cases, the existing architecture requires specific design solutions and many costly refits to counteract obsolescence, accommodate a new function and bring aesthetic value to the urban environment (Ellison et al., 2007). Conejos, Langston, Chan, & Chew (2016) highlighted these concerns as a conclusion from semi-structured open-ended interviews with professionals directly involved in repurposing heritage buildings in Australia. The research revealed compatibility with design requirements and compliance with regulations and codes as the primary challenges encountered when up-cycling buildings with an alternative function. In a similar vein, Kurul (2007) explored two adaptive reuse case studies in London through in-depth interviews with the stakeholders involved in various stages of the project, and research of archival planning documentation. The study indicated the interdependency between project complexity and investment risks, which arises from the evolutionary and reiterative nature of shaping the end-product. It was shown that innovative approaches, which allow retaining a certain level of flexibility to facilitate change and exploit emerging opportunities, are crucial when considering repurposing urban structures. While multi-storey garages were developed for private vehicles, and the dimensions of a car were the primary measures during the design stage, several constraints for their up-cycling have been identified, which increases the adaptive reuse complexity. The limitations indicated by Henley (2007) include low floor-to-floor height, the layout of ramps, staircases and the grid of supports that are difficult to be adjusted to an alternative use. Many garages have some individual features, for instance an atrium or characteristic elevation cladding, which involve more advanced technical solutions to enable the up-cycling process. Furthermore, concrete, as the primary material used to build modern movement garages, deteriorates from water penetration and chemical imbalances in the aggregate, thus increasing the potential costs of repurposing (Christodoulou, 2013; Gooranorimi & Strategies, 2018). Therefore, the adaptive reuse of such a structure is associated with increased project complexity and investment risk, and therefore demolition may be chosen as an appropriate strategy (Henley, 2007).

Another constraint for repurposing buildings is the existing policy (Cantell, 2005). In many cities, zoning codes do not allow for developing a new function in a structure previously utilised for another purpose. In this context, a crucial challenge is to obtain approval for the implementation of an alternative use. When considering repurposing buildings for innovative functions, for instance UA, lack of experience in such practices often results in numerous uncertainties and regulatory gaps in the legal framework, and lead to the rejection of the proposal (Specht et al., 2015). A lack of knowledge and experience on the part of decision makers regarding the new use bring limitations which may lead to the demolition of the disused structure.

A great deal of previous research into up-cycling indicated the benefits of such projects. A growing body of literature highlights the lower costs of repurposing a structure compared with demolition and new build (Ball, 2002; Douglas, 2006; Kohler & Yang, 2007). Douglas (2006) indicated that utilising existing infrastructure, for instance, the foundations or essential services, reduces the time required for construction, thus minimising financial expenses. Shipley et al. (2006) revealed that up-cycling buildings often results in a higher return on investment than a new build. In comparison, demolition is an expensive, disruptive, wasteful, dangerous process, which incurs more embodied energy in the development activities. These issues are expanded in the case of adjoining buildings, of which only one is obsolete and planned to be demolished (Douglas, 2006), for instance a multi-storey car park attached to a shopping centre or a hotel. The increased complexity and costs of such an investment are crucial arguments for considering adaptive reuse instead of demolition and new build (Balaras, Dascalaki, & Kontoyiannidis, 2004; Kohler & Yang, 2007; Kurul, 2007).

According to Douglas (2006), repurposing building stock is associated with considerable cultural, historical and architectural values, which maximise the social profitability of the existing structure and urban district. This conclusion is rooted in the approach that the aesthetic and continuity of the urban fabric play a crucial role in shaping the attitudes and behaviours of the local community and visitors (Jacobs, 1961; Lynch, 1960). Up-cycling buildings with a new function allows for retaining the character of a streetscape, thereby enhancing the psychological reassurance of urban dwellers (Ball, 2002; Bullen & Love, 2010; Douglas, 2006). In contrast, demolition and new build alter the perception of the district from the residents' perspective and often imposes an unwanted change in their every-day habits (Jacobs, 1961). In many cases, the deterioration and obsolescence of a building negatively affects the local community, for instance due to growing crime or an increase in vandalism. Ball (2002), Douglas (2006), Mohamed et al. (2017) and Velthuis & Spennemann (2007) indicated that adaptive reuse, used as a tool in the social planning of a defunct district, restores informal social control and improves the perception of neighbourhood safety, thereby contributing to the improvement of community cohesion. Although the social benefits arising from repurposing buildings are difficult to measure, the potential improved social performance of an up-cycled structure or district may become a key opportunity preventing demolition and new build, even when the building fails a financial analysis assessment (Douglas, 2006; Mohamed et al., 2017).

Adaptive reuse represents the most sustainable approach to the development and utilisation of a building from the circular economy perspective. Sanchez & Haas (2018a, 2018b) indicated product recovery management, design for disassembly, sequence planning, life cycle assessment, adaptability, closed material loops, deconstruction, and dematerialisation as crucial circular building principles. In the context of these principles, the shift from demolition and new construction to up-cycling contributes to urban environmental sustainability (Sanchez & Haas, 2018b). The advantages include reduced material, energy and transport demand (e.g. Boschmann & Gabriel, 2013; Velthuis & Spennemann, 2007; Wilkinson et al., 2009). In the EU, demolition and construction waste comprises 10 to 33 percent of total waste streams. Demolition waste accounts for 40 to 50 percent of this waste, renovation 30 to 50 percent and construction 10 to 20 percent (Brodersen, Juul, & Jacobsen, 2002). When making design decisions regarding adaptive reuse, material that can be utilised in a closed-loop cycle, perform further retrofit actions and benefit the environmental performance of the building should be selected to contribute to the environmental sustainability of the operation (Balaras et al., 2004). A decision-making process rooted in the principles of the circular economy is often based on the comparative LCA of renovation and demolition, followed by the new build. The review of relevant literature of this method of comparing scenarios for the future of existing urban structure is presented in APPENDIX A.

Considering all of this evidence, it seems that there may be good reasons for both scenarios revealed by Henley (2007) for the future of modern movement car parking structures. However, the social, economic and environmental benefits of repurposing buildings for alternative use that were explored indicate a requirement to analyse the up-cycling potential of this architectural type and investigate if it can meet the demands of an innovative function, which is now needed in cities. As the present research studies, for the first time, the adaptive reuse potential of modern movement car parking structures for CEA from an architect's perspective, it focuses on the initial design phase. It is necessary to explore the opportunities and limitations for such a retrofit to develop an initial design scenario which would create a foundation for analysing whether this architectural type may gain significance regardless of its primary use. The following chapter initiates the theoretical investigation by reviewing the current literature on the planning, architectural and environmental opportunities and limitations for the adaptive reuse of buildings for CEA, and validates the data obtained by applying this to the case studies.

Chapter 4: Investigation into the planning, architectural and environmental opportunities and limitations for the adaptive reuse of urban structures for controlled environment agriculture

4.1. Introduction to Chapter 4

This chapter has been developed as research for design, which analyses the existing literature from the architect's perspective and validates the data generated through exploratory case studies. The main aim of the literature review is to research and document the planning, architectural and environmental opportunities and limitations for up-cycling inner-city modern movement garages for CEA. Then, three case studies of CEA operations implemented within or upon existing urban structures are evaluated through the planning, architectural and environmental framework developed by the literature review. The results of the research for design provide the theoretical background for the further stages of the PhD investigation, including interviews with experts, and the development of the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA.

4.2. Planning considerations

The literature on the current planning context for implementing building-based CEA highlights that in most cities, such as Berlin (Germany) or Barcelona (Spain), food planning is not an element of urban planning strategies. While building-integrated CEA is seen as an innovation in cities, the lack of experience in such practices often results in numerous uncertainties and regulatory gaps in the legal framework, which often lead to the rejection of an agricultural proposal (Sanyé-Mengual et al., 2016; Specht et al., 2015). The possibility to make an exception for a single case, or to change a contrary planning approach, depends on the political, market, spatial and social circumstances of a specific urban area. For instance, the analysis of interviews conducted with the stakeholders from Berlin (Germany) by Specht et al. (2015) reported the positive attitude to the integration of ZFarming into existing policies. However, the decision makers indicated several limitations which need clarification, such as the potential target group of the activity and the presumption that CEA may become too commercial. The results of interviews conducted with decision makers in Barcelona (Spain) by Sanyé-Mengual et al. (2016) on the integration of rooftop greenhouses within the existing urban fabric highlighted substantial barriers for the alteration of the current legal framework to implement this type of building-based UA. The crucial constraints were associated with the general perception of soilless cultivation techniques as not *real agriculture* as well as several environmental, economic and social uncertainties. These studies indicate that repurposing buildings for CEA requires innovations in planning documents. However, a lack of knowledge on the social, economic and environmental performance of building-based UA constricts policy change in favour of the adaptive reuse of urban structures for CEA.

Another planning issue concerns the readjustment of UF permitting and zoning processes. Mukherji and Morales (2010) reported two ways to include UA in zoning: either by establishing a UF district or by considering UA as a use which is forbidden, conditional or permitted, depending on the urban area. Several cities have already amended permitting and zoning processes not to allow the permanent use of existing lots or buildings for UA, but enable interim use (Meenar, Featherstone, Cahn, & McCabe, 2012). For instance, in the land use and policy study published by the city of Philadelphia (USA), it is highlighted that *urban agriculture should generally be pursued via temporary arrangements* (Wachter & Scruggs, 2010, p. 25). Similarly, in the UK planning context, meanwhile leases are seen as an opportunity to enable food cultivation in compact and dense urban areas, for instance when intended development is stalled (Davis, 2018). Such approaches reveal that decision makers consider CEA as the temporary use of an existing urban structure, which, from the farmers' perspective, potentiates uncertainties regarding the viability of the operation in a given time frame (Thomaier et al., 2014). Thomaier et al. (2014) indicated that in practice, meanwhile leases for ZFarming often encourage and stimulate innovative decisions, for instance the design of modular growing units which can be easily transported to another location, or the utilisation of shipping containers for CEA. Such experimental attempts deliver crucial evidence on the performance of building-based CEA, and improve the perception of how it can be implemented and operated within the existing urban fabric, thereby contributing to the amendment of the open legal framework (Specht et al., 2015).

A positive planning attitude is observed in the USA, where cities such as Chicago have started to incorporate UF in land-use, and launched food policy planning. Some towns began specific public programs, and established organisations to assist UF projects by providing technical and legal support and enabling knowledge transfer between urban farmers. The New York Department of City Planning amended a zoning resolution to allow for developing rooftop greenhouses in dense urban areas. Further modifications in zoning texts were introduced to encourage the implementation of rooftop greenhouses such as Gotham Greens in Greenpoint, Brooklyn or Eli Zabar's on the East Side of Manhattan. These facilitations focus on commercial architecture, where the rooftop greenhouse can be excluded from Floor-to-Area Ratio limits when it only includes plant cultivation supported by a rainwater harvesting and reuse system, and where the building does not contain sleeping accommodation (Ackerman et al., 2013). The cities of Boston and Philadelphia (USA) are considering a similar resolution. Such innovations in urban planning are required to enable the spread of CEA as a secondary food source in growing cities.

4.2.1. Opportunities and limitations for the implementation of building-based urban agriculture from the stakeholders' perspective

To date, several studies have interviewed stakeholders to get a better understanding of how they perceive UA, and based on the data obtained, conceptualise opportunities and limitations for allowing the implementation of food growing practices in cities (Cerón-Palma et al., 2012; Mulligan, Archbold, Baker, Elton, & Cole, 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). The review of these sources is summarised in Table 7. Due to the small number of existing CEA operations, such investigations are based on a theoretical framework.

In their research Specht et al. (2015) conducted 38 guided interviews with stakeholders considered relevant for the assessment and implementation of building-based farming projects in Berlin (Germany), including eight UF activists, eight members of farmers', architects', horticulture, real-estate, and roof garden associations, seven stakeholders from the planning domain, including architects, landscape architects, environmental planners, roof garden planners, and soil and composting planners, four public administration staff, seven UF researchers and four food distributors. The significant benefits indicated by interviewees were seen at the social level. Further values were identified in environmental, economic and aesthetical dimensions. The main limitations for the development of building-based farming arose around the potential products and technology applied, the ease of use, access, and understanding this specific agricultural operation, as well as economic, social, environmental and aesthetic risks. Cerón-Palma, Sanyé-Mengual, Oliver-Solà, Montero and Rieradevall (2012) invited 15 experts in agriculture, engineering, environmental sciences and city planning to discussion seminars for exploring the limitations and opportunities of the implementation of RTGs in Mediterranean cities in Europe. During the research, economic, technological, environmental and social categories of benefits and constraints were identified. Sanyé-Mengual et al. (2016) conducted 25 semi-structured interviews with nine policy-making staff at the local and national level, seven stakeholders involved in UA, five architects, one planning lawyer, one food distributor, one RTG promoter and one manager of a green space company. The study indicated social advantages associated with building-based farming as being prominent from the stakeholders' perspective. Other benefits were divided across environmental and economic groups. Environmental, technical, social and economic barriers were identified during the study. Mulligan, Archbold, Baker, Elton, & Cole (2018) carried out 18 informant interviews with stakeholders in Toronto (Canada), including four provincial and municipal policymaking staff, four members of not-for-profit organisations at the provincial and municipal levels, four funders, three landowners, and three urban farmers. The discussions conducted from the perspective of environmental sustainability, population health and urban governance presented social categories as primary areas of interest. Additional benefits from UA were associated with economic development and employment, land use and production, partnership and policies. The main barriers identified were related to economic, social, environmental and aesthetic risks.

The social benefits of UF indicated as the most prominent for stakeholders are those on both the global and the local scale. Regarding the existing global food system, building-based farming is seen as an opportunity to improve the transparency of food production and distribution (Sanyé-Mengual et al., 2016; Specht et al., 2015). UA is expected to bring urban residents closer to food cultivation and re-connect them with food sources (Specht et al., 2015). On the local level, stakeholders associate UF with educational opportunities, which broaden urban residents' knowledge about a healthy diet, agriculture and a sustainable way of living in cities (Sanyé-Mengual et al., 2016; Specht et al., 2015). Further social values on the urban scale are recognised in the development of farming practices as an innovative space, which may be used for increasing the physical activity level of residents (Mulligan et al., 2018), both for leisure as well as experiments and creative actions (Sanyé-Mengual et al., 2016; Specht et al., 2015). Significant advantages are associated with diet-related improvements, including enhancing community food security (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015), the provision of nutritional vegetables and fruits, and a reduction in diet-related diseases (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). Further benefits are identified when residents are engaged in the UF activity, which offers potential for community building and empowerment (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2015) including the integration of vulnerable groups of people (Mulligan et al., 2018).

Regarding social barriers for developing building-based UA, implementing these practices is seen as a high-cost investment superior to potential social improvements (Sanyé-Mengual et al., 2016). While stakeholders perceive CEA as detached from the land, unnatural, providing low-quality products and engaging an expensive technology, they assume similar opinions to be confirmed by the local community (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). Therefore, residents' involvement is not expected to be high when considering possible farming activities within and upon buildings. On the other hand, the implementation of building-based CEA with an integrated social dimension is seen as a strategy to improve the economic performance of an urban district (Specht et al., 2015). In turn, such a process is associated with possible adverse urban phenomena, such as gentrification and an increase in real-estate prices (Specht et al., 2015). Moreover, the technocratic nature of CEA was identified as the primary point where the local authority lost interest in further involvement. Producing food in a controlled environment is seen as too artificial, and is associated with growing vegetables of low nutritional value and distorting the idea of agriculture (Sanyé-Mengual et al., 2016). Further constraints are associated with health risks caused by air pollution, contaminated wastewater (Specht et al., 2015) or personal injury, which may happen when the community is involved in the farming activity (Mulligan et al., 2018).

Environmental opportunities potentially derived from building-based CEA include a reduction in food miles and associated improvements, including a reduction in CO_2 emissions and fossil fuel consumption (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). The local authority considers developing technical synergies between the farm and the accommodating building as beneficial for energy and water use efficiency, and CO_2 emissions. These values are perceived as an opportunity to reduce the adverse environmental impacts of existing buildings and to move to zero-consumption architecture (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016).

At the same time, the development of CEA is associated with environmental burdens arising during the operation of the farm. The first issue is the lack of evidence that presents the ecological benefits derived from building-based CEA, which makes the implementation of these farming installations questionable regarding their environmental impacts (Specht et al., 2015). The second limitation is the unsustainable management of the building-based farm, which may negatively impact its resource- efficiency. This issue may arise at the initial stage of the UF practice development, where unsustainable materials could be chosen for the construction of the farm, and continue in the operational phase, where the need to optimise the internal environment parameters for plant growth could increase the use of resources. (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). A significant limitation is management of organic waste produced during soilless cultivation processes, which cannot include using organic matter as fertiliser (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). All of these obstacles question the environmental sense of developing building-based CEA, which often engages spaces seen by stakeholders as a resource for implementing more important uses or technologies, for instance, PV panels on rooftops of existing buildings instead of RTGs (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016).

From an economic perspective, CEA may benefit the redevelopment of urban districts through the adaptive reuse of obsolete buildings. For the local authority, it is often a key constraint to repurpose the unused building, and CEA is perceived as a valuable solution (Specht et al., 2015). Such investments are expected to bring economic savings related to upcycling buildings with all of the existing infrastructure instead of implementing a new architectural form. Some opinions indicate the integration of a single un-utilised area (e.g. a rooftop) in or on a structure which is still in use as economically beneficial from the whole building's perspective (Sanyé-Mengual et al., 2016; Specht et al., 2015). Further economic values are associated with the reduction in costs related to conventional long-distance transportation chains (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). Local food production is a new business opportunity, which allows for testing organisational and technological approaches for business models. The possibility exists to apply for financial aid for developing UF businesses and products (Cerón-Palma et al., 2012), which may benefit the city by offering new income and job opportunities (Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). CEA projects may become an innovation, which are needed to improve regional value chains, create local labels and then be showcased (Sanyé-Mengual et al., 2016; Specht et al., 2015). Moreover, interviews conducted by Mulligan et al. (2018) revealed that a UF project is expected to indicate quantitative indicators. Presenting the number, size and type of farming installations, the types and amount of food produced, the economic value of a determined cultivation area and the extent to which the grown product may replace imported food are significant for predicting the economic viability of the UF operation.

The financial limitations for the development of building-based CEA were associated with high costs for infrastructure and technology (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). Further investment must be undertaken into professional staff training and management (Cerón-Palma et al., 2012). The high initial costs required, and narrow profit margins for agricultural products, are expected to be returned over a long-term perspective (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016). However, this does not guarantee economic stabilisation for the business, and can result in building-based CEA operations being taken over by large companies (Specht et al., 2015). Moreover, UF within and upon buildings is seen as being in competition with other uses with higher economic priority in urban areas (Sanyé-Mengual et al., 2016; Specht et al., 2015) and with rural farming (Specht et al., 2015).

Regarding technical opportunities for building-based farming, a considerable amount of literature has been published on climatic architecture; various forms of CEA and numerous examples have been already built in different climatic zones. Drawing on that experience, building-based CEA may be designed as an energy-efficient, productive architecture, which contributes to the self-sufficiency of urban areas (Cerón-Palma et al., 2012). However, the adaptive reuse of buildings for UA is a technologically sophisticated process, which can result in overloading the structure. When the structural assessment indicates that the carrying capacity of the existing architectural form is too low to accommodate UF installations, reinforcement should be done to complete the investment (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2015). These limitations are further hindered by legal barriers, for instance for rooftop usage, which could limit the areas available for UA within and upon buildings (Sanyé-Mengual et al., 2016) or lead to potential disputes and litigation (Mulligan et al., 2018). Other technical constraints are seen in the logistics of the product in an urban area, as well as urban air pollution and crop management (Sanyé-Mengual et al., 2016).

Aesthetic opportunities are perceived on the scale of the individual building, as well as in the urban dimension. Developing UA within or upon existing structures is considered an innovative architectural quality, which has the potential to improve the aesthetics of buildings by using innovative methods, such as greening the building (Specht et al., 2015). When multiplying such solutions in an urban context, the relationship between architecture and landscape could become more aesthetically consistent (Specht et al., 2015). On the other hand, some stakeholders highlighted that the greenery implemented in and on existing architectural forms might not be visible from the human perspective. Therefore, several interviewees indicated little or no aesthetic values to be added from building-based farming (Specht et al., 2015).

According to Mulligan et al. (2018), opportunities for innovative partnerships and policies arise when bringing agriculture to cities. These values include establishing organisations aimed at supporting urban farmers, and creating inter-divisional, inter-governmental and cross-sectoral collaborations. The connections developed may lead to the amendment of existing policies to support UA and include food planning. A further partnership may arise between urban farmers and residents, for instance through organising educational tours of UF sites. Moreover, the spread of UF in cities is positively associated with a reduction in poverty and health care costs (Mulligan et al., 2018).

4.2.2. Planning strategy at the initial stage of design for repurposing buildings for controlled environment agriculture

The evidence presented in this section suggests that from the stakeholders' perspective, planning opportunities and limitations for up-cycling buildings for UA can be placed within the social, environmental, economic, technical and aesthetic domain of urban development. Planning and policy is another crucial area which could benefit from the implementation of building-based UA. The studies analysed indicate that the perception of these opportunities and limitations depends on the planning context of the area where building-based CEA aims to be developed (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). Therefore, the exploration of urban planning documents and objectives for the specific urban district is the first step to be taken when conceptualising the proposal for a UA operation (Sanyé-

Mengual, Cerón-Palma, Oliver-Solà, Montenero, & Rieradevall, 2015). These papers indicate site allocations, building features and particular demands and priorities regarding specific urban areas, which may offer new opportunities or create barriers for developing building-based UF (Campbell, 2016). The analysis and identification of the opportunities and limitations for up-cycling urban structures for CEA within the specific planning context plays a crucial role in building an argument for making a case when engaging with the local authority (Davis, 2018).

While for urban farmers, it is often a significant constraint to persuade a council to enable implementing UA (Campbell, 2016), new organisations are emerging to assist and advise on the legal framework. For instance in the UK the Sustainable Food Cities initiative has been created to develop a cross-sector partnership of local public agencies, academics, businesses and NGOs aimed at improving food quality, encouraging UA, and promoting healthy and sustainable food. Their research report *Engaging with local authorities* (Davis, 2018) provides valuable insights into how to make a case when discussing the UF initiative with stakeholders. The document recommends defining the key drivers and motivations for implementing UA. Applying this recommendation at the initial stage of the design thinking process allows the creation of a direct link between the objectives for the urban area, defined in planning documents, with opportunities, conceptualised as key drivers and motivations, which may potentially arise from up-cycling a building for CEA within the district analysed from the stakeholders' perspective. The development of such a planning proposal has the potential to improve the decision makers' perception and acceptance of the adaptive reuse of buildings for CEA, and enhance the project at the local level (Davis, 2018).

Table 7: Summary of opportunities and limitations for building-based farming from stakeholders' standpoint: comparison of analysed studies. Sources: Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015

	Cerón-Palma et al. (2012)	Specht et al. (2015)	Sanyé-Mengual et al. (2016)	Mulligan et al. (2018)
Social opportunities				
Improved transparency of food production		+		
Connection between consumers and food production		+	+	
Improved consumer awareness	+	+	+	+
Improved food quality	+	+	+	+
Nutrition-related health outcomes (e.g. diabetes)				+

Improved community food security	+	+	+	+
Educational opportunities	+	+	+	
Community building (empowerment, fun)	+	+	+	+
Spaces for experiments and creativity				
Improved living quality	+	+	+	+
Improved physical activity levels				+
Social limitations				
Lack of acceptance of soilless growing techniques		+	+	
Social disparities in access to systems and products (gentrification)		+	+	
Need to train qualified personnel	+		+	
Personal injury risks				+
Health risks (air pollution, water contamination)		+		+
Management barriers			+	
Little or no social benefits (general)		+		
Environmental opportunities				
Reduced emissions and transport (food miles)	+	+	+	
Improved organic waste recycling	+	+	+	
Improved water use efficiency	+	+	+	
Improved building energy efficiency	+	+	+	
Carbon and contamination fixation				
Reduced pressure on agricultural land	+	+	+	
Sustainable architecture and urban landscape		+		
Increased horticultural yields		+		
Enhanced closed cycles		+		
Naturalisation of the city	+	+		+
Environmental limitations				

Perception of little environmental benefit		+	+	
Limitations to recycle organic matter in nutrient solution for the hydroponic system		+	+	
Environmental impact of construction materials	+		+	
Risk of unsustainable management			+	
Reduction of surface area for solar panels	+			
Economic opportunities				
Adaptive reuse of derelict buildings and spaces	+	+	+	
Reduction of costs related to conventional agriculture	+	+		
Local economic development		+	+	+
Potential products and high yields		+	+	+
New business models, income and employment	+	+		+
Innovation to attract investors and showcase	+	+		
New marketing opportunities		+	+	
Availability of financial aid for new products	+			
Improved regional value chains		+		
Economic limitations				
Little or no economic benefits (general)		+		
High costs of associated technology	+	+	+	+
High costs of management and investment	+		+	+
Lack of trained staff	+	+		
Risk of large companies taking over the project		+		
Competition with other uses		+	+	

Competition for rural farmers		+		
Narrow profit margin for horticultural products	+		+	
Consumer and investor acceptance	+		+	
Long-term repayment	+			
Exclusion of certain crops		+		
Technical opportunities				
Improved urban self-sufficiency	+	+	+	
Adaptive reuse of buildings				
Experience in greenhouses and climatic architecture	+			
Energy-efficient productive architecture	+			
Technical limitations				
Integration of UF within existing buildings	+	+	+	
Building overloading and need of reinforcement	+		+	
Risk of contamination (air pollution)	+	+	+	+
Logistical constraints in urban areas			+	
Crop management			+	
Legal barriers for building usage			+	
Aesthetical opportunities				
Improved building aesthetics		+		
Improved city landscapes		+		
Aesthetical limitations				
Noise and smell pollution		+		
Little or no aesthetic benefit		+		+
Partnerships and policies				
Improved public awareness				+
New institutional supports and policies instituted for UA				+
New inter-divisional, inter-governmental and/or cross-sectoral collaborations				+

4.3. Architectural considerations

Repurposing urban structures for CEA can be done by converting the interior of a building into a plant factory (PF) with sunlight (PFSL) or artificial light (PFAL) (Kozai et al., 2015) as well as utilising a building envelope by developing a rooftop greenhouse (RTG) (Montero et al., 2017; Sanyé-Mengual, Cerón-Palma, et al., 2015) or integrating a façade farm (FF) (US 8,151,518 B2, 2012; Jenkins, 2018) (Fig. 25).

Figure 25: Typology of building-based CEA in urban areas, by Szopinska-Mularz

CEA developed as an indoor system is defined in the existing literature as a plant factory (PF) (Graamans, van den Dobbelsteen, Meinen, & Stanghellini, 2017; Ting et al., 2016; Tsitsimpelis et al., 2016). Depending on sunlight accessibility, these farming operations are further divided into a PFSL and a PFAL (Kozai, Niu, & Takagaki, 2015). A PFSL is also known as VF, as both types are conceptualised as large-scale food production systems lit by sunlight (Shamshiri et al., 2018). In their research on PFs, Graamans, van den Dobbelsteen, Meinen, & Stanghellini (2017) created a link between these indoor farming operations by defining VF as a multi-storey PFSL. According to Kozai (2013), PFs are expected to maximise plant growth in cities with maximum resource use efficiency, minimal adverse environmental impacts and minimal costs for resources. PFs are increasingly implemented in derelict factories in urban areas as commercial projects (Tomlinson, 2015).

A greenhouse is a type of CEA which can rely only on sunlight. In urban settings, greenhouses are being increasingly developed as RTGs (e.g. Sanye-Mengual, Ceron-Palma, Oliver-Sola, Montero, & Rieradevall, 2015; Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall, 2015; Shamshiri et al., 2018; Specht, Siebert, & Thomaier, 2015). While a large body of literature has investigated the optimal design of rural greenhouses concerning optimal solar radiation transmissivity and energy-efficiency, this research is considered equally valid regarding urban applications (Montero et al., 2017; Sanye-Mengual et al., 2015). RTGs are mainly implemented as large-scale commercial projects, such as the Gotham Greens RTG developed on the roof of a warehouse in New York (USA) (Fig. 26).

Figure 26: Gotham Greens, New York, USA, RTG. Retrieved from www.gothamgreens.com/our-farms/ (accessed: 09.05.2019)

The façades of urban buildings are vertical spaces with the potential to become productive by utilising sunlight for food cultivation. Proposals for FFs seek to explore and modify the design and thermal features of glazed elevations as the architectural elements which may accommodate agricultural production and offer benefits for the thermal comfort of a building (US 8,151,518 B2, 2012; Jenkins, 2018; Stec, Van Paassen, & Maziarz, 2005). The current literature investigates these FF prototypes as shading systems, which reduce energy use for heating in the winter and cooling in the summer, thus improving the annual thermal performance of a building (Stec et al., 2005). However, there is no existing significant example of an FF.

All CEA types are classified as closed plant production systems (CPPS), which protect cultivated plants from unfavourable environmental conditions, and extend the growing season or enable plant cultivation on a year-round basis (Sethi, 2009). From the architectural perspective, each type of CEA offers different opportunities for sunlight access, the scale of agricultural production and the implementation of sustainable technologies, which affects the viability of the up-cycling process. Thus, investigating the adaptive reuse potential of a building for CEA through the framework of the conceptualised types is crucial for developing a viable initial design scenario. Considering this criterion, four topic areas emerge from the literature analysed: (1) architectural form for CEA, (2) orientation of an architectural form for CEA, (3) materials to enclose a space for CEA, (4) structure of the building up-cycled for CEA.

What follows is the literature review of these themes through the framework of CEA types relevant for up-cycling buildings for food cultivation. The summary of findings is presented in Table 8.

4.3.1. Architectural form for controlled environment agriculture

RTG

A large and growing body of literature has investigated an optimal greenhouse envelope design featured in quantitative experimental studies. It was demonstrated that an envelope design for a greenhouse is crucial for optimising solar radiation transmissivity, increasing solar energy gain and energy retention, which benefits the productivity of the agricultural system and improves its energy efficiency (Ahamed, Guo, & Tanino, 2018b). There are two types of greenhouses: single-span and multi-module or multi-span. Multi-span greenhouses consume 4-10 percent less heating energy in comparison with single-span greenhouses of different types under temperate climatic conditions (Djevic & Dimitrijevic, 2009). This energy-efficiency is a result of a smaller external surface area in comparison with a single-span greenhouses (Hanan, 2017).

Another critical design consideration on the architectural form of a greenhouse is the roof geometry, which affects internal air temperature, heat loss and solar energy gain in greenhouses. Five shapes, usually considered for crop production, are presented in Figure 27. The experimental study conducted by Sethi (2009) reported maximum solar radiation gained by an uneven-span shape single-span greenhouse at all latitudes during each month of the year, and the lowest solar radiation received by a Quonset shape. When comparing different greenhouse shapes in different months, the highest air temperature was observed in an uneven-span shape greenhouse, while the lowest was in a Quonset shape (Sethi, 2009). Ahamed, Guo, & Tanino (2018a) compared all five greenhouse shapes with additional heating needs under the cold weather conditions of Saskatoon (Canada) and reported the highest solar radiation as received by an uneven-span roof shape. In contrast, the Quonset shape was associated with the lowest solar radiation gain. However, the heat loss in the uneven-span greenhouse was reported as high due to the large exterior surface. The results indicated that the high heat loss per unit of the cover area of an uneven-span roof shape exceeds the benefits from the solar heat gain. Moreover, the annual heating requirements were reduced by about 7.6 percent in the Quonset shape greenhouse in comparison with the uneven-span roof shape greenhouse. One obstacle identified during the research was that the Quonset roof shape could not be built as a multi-span greenhouse. Therefore, in terms of energy-efficiency, the uneven-span roof shape greenhouse was considered more advantageous for a multi-span gutter connected greenhouse, while the Quonset shape roof benefits a free-standing single-span greenhouse.

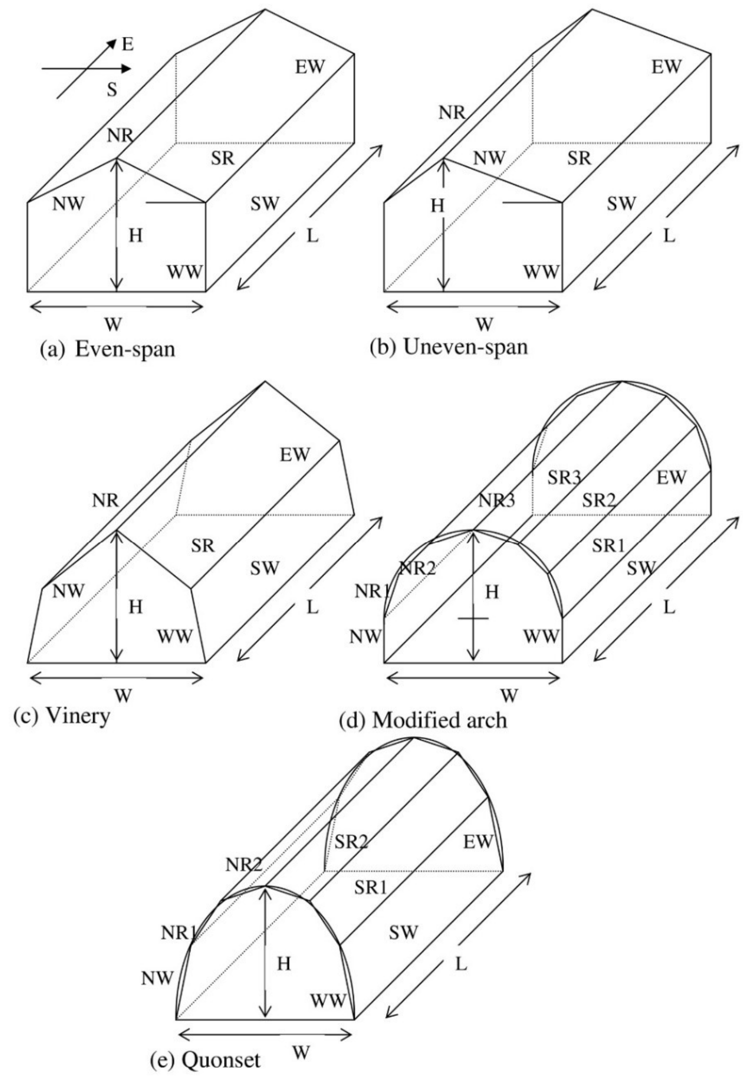


Figure 27: The common conventional greenhouse shapes. Source: Sethi, 2009

Çakir & Şahin (2015) conducted an experimental study to explore which single-span greenhouse shape is optimal regarding the availability of solar radiation in the temperate climatic zone. The study reported the Quonset shape as the most beneficial. In another major study, Ahamed et al. (2018a) used a heating simulation model to explore which greenhouse design parameters are crucial for reducing heating and cooling demands in high northern latitudes. The best results were observed when the length-width ratio of the greenhouse was more than 1, with the roof angle kept between 25 and 30° for energy saving reasons.

FF

Studies on repurposing elevations for CEA focus on food growing installations located in a cavity between the layers of a double skin façade (US 8,151,518 B2, 2012; Jenkins, 2018; Stec et al., 2005). An advanced concept of an FF is a Vertically-Integrated Greenhouse (VIG), developed and patented (US 8,151,518 B2, 2012) by Adams and Caplow. VIG is designed as a hydroponic system placed between double-skin building façades. Plants are cultivated on movable arrays of trays, which at the same time serve as mechanical shading devices. However, there is currently no existing example of such a system. The second identified type of FF was proposed and built by Jenkins (2018) (Fig. 28). Growing channels were developed in a double helix form and installed together with a filtration unit and aquaponic tank in the cavity of a module of a VS-1 façade system produced by Glassolutions. The design enables moving the crops to distribute access to sunlight evenly. One module of this FF is 3 m high, 2.5 m wide and 0.35 meters deep. This FF was theoretically tested using simulation software on a façade of a supermarket, an office building and a hospital due to the potential benefits in terms of food supply and energy savings (Jenkins, 2018).

Figure 28: The Biospheric Project, Irwell House, Salford, UK, The prototype of an FF. Source: Jenkins, 2018

PFSL/VF

Research on the up-cycling potential of an existing architectural form for a PFSL or VF focuses on recognising the opportunities for solar radiation transmission to the interior, and space availability for CEA. In his theoretical book on VF, Despommier (2010) indicated restricted sunlight availability as a significant limitation for repurposing buildings for food cultivation and recommended the construction of new developments for meeting the requirements of CEA. A much more detailed explanatory investigation of the adaptive reuse potential of a derelict factory, Irwell House in Salford (England) was conducted by Jenkins (2018). The team of architects and researchers designed and built a PFSL within the building. Experiments on the design of internal food cultivating units and their location within the building highlighted the availability of space and sunlight as the primary concerns for up-cycling buildings for CEA. For the availability of space, the crucial limitation indicated was the structural capacity of the derelict factory, as the structural assessment showed that only one floor was able to accommodate a CEA operation. Regarding the sunlight access, the highest and most satisfying productivity was noted when the growing units were installed along the north-eastern and south-eastern facing elevations with windows. Such locations maximised solar radiation to the internal parts of the building, which benefited plant growth and quality (Jenkins, 2018). No data on the relationship between the architectural form and the thermal performance of the PFSL, including heating or cooling requirements, was presented in the research.

PFAL

Research and practice show that warehouses and industrial buildings are the architectural forms frequently chosen for adaptive reuse for a PFAL, due to maximum flexibility in the interior arrangement caused by high ceilings and vast distances between vertical structural elements (Brown-Paul, 2016; Chance et al., 2018; Tomlinson, 2015). For instance AeroFarms developed hydroponic plant factories in a former steel mill, nightclub and paintball tag arena in the USA (Brown-Paul, 2016), Urban Organics cultivate organic plants in a former brewery in Saint Paul (USA) while GrowingUp utilises hydroponic technology for quality vegetable growing in an industrial warehouse in London (UK) (Lu & Grundy, 2017). A recommendation for selecting buildings to be up-cycled for a PFAL was made by Kozai (2013), who indicated that CEA lit solely by artificial lighting should be implemented in a *thermally well-insulated and nearly airtight warehouse-like structure covered with opaque walls* (Kozai, 2013, p. 449). The utilisation of such an architectural form allows for the specific control of different parameters of the internal environment and offers potential in terms of resource-efficiency (Kozai, 2013).

An innovative architectural approach to the selection of a PFAL's envelope is up-cycling shipping containers. Utilising these structures for CEA was introduced in the industrial domain over the past few years (e.g. FreightFarms, 2016; GreenTech, 2016). Tsitsimpelis, Wolfenden, & Taylor (2016) conducted a detailed investigation of retrofitting opportunities for a shipping container for plant cultivation. By taking a system design approach, the prototype of the grow-cell based on a 12 m × 2.4 m × 2.5 m shipping container was developed as a modular farm (Fig. 29). The primary considerations included engineering requirements for the optimisation of the internal environmental parameters. The study revealed that improvements in environmental control technologies are required for further development of CEA in shipping containers. Nevertheless, the prototype of a grow-cell is already being used and serves for the systematic investigation of areas crucial for the future of CEA, including energy efficiency and whole system running costs.

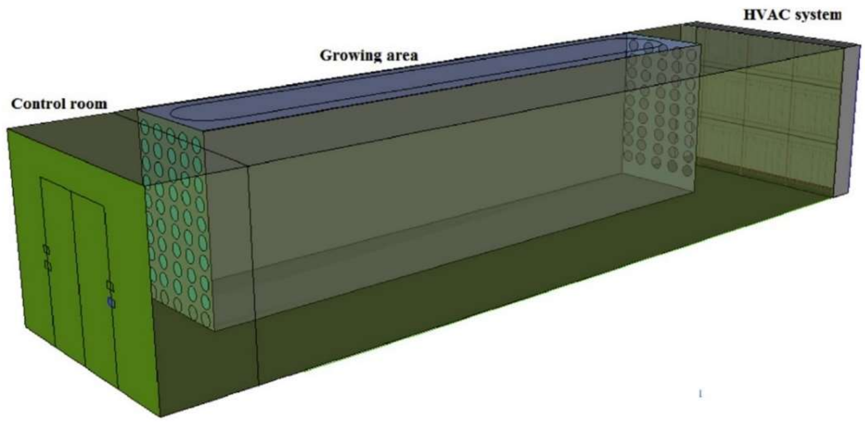


Figure 29: Grow-cell prototype drawing showing the layout of the modified freight container. Source: Tsitsimpelis et al., 2016

4.3.2. Orientation of the architectural form accommodating controlled environment agriculture

RTG

RTGs located in temperate climates require significant supplemental heating loads for cultivating plants in winter seasons. Making design decisions on the orientation of a greenhouse is crucial for maximising solar energy transmission, which allows lower heating loads, thus causing energy savings and a reduction in the costs of a UF operation (Dragicevic, 2010). Previous studies have explored greenhouses constructed along east-west (EW) and north-south (NS) orientations (longer axis) for raising off-season vegetables at different latitudes. For maximising solar transmission in the northern hemisphere, the EW orientation is most advantageous. For instance Dragicevic (2010) conducted an experimental validation of the orientation of a greenhouse located in Belgrade (Serbia). The measured solar radiation data for the south wall and horizontal surface revealed that the EW orientation of the longer axis maximises solar radiation availability. Similarly, to measure solar transmissivity distribution on the ground surface of a greenhouse located in Athens (Greece), Papadakis, Manolakos, & Kyritsis (1998) positioned a greenhouse model on a goniometric mechanism, which allowed for changing the greenhouse azimuth. The study reported that during winter months, the EW orientation is preferable to the NS. Improved solar transmissivity induced by the lower inclination of the sun at North European latitudes contributes to the reduction in the energy requirements in winter months (Papadakis et al., 1998). Chandra (1976) conducted a theoretical comparison of two gothic arch-shaped greenhouses, the first with EW and the second with an NS orientation in the northern latitudes of Canada. The study concluded that the EW oriented agricultural system required 20 percent less heating than the NS oriented one. Stanciu, Stanciu, & Dobrovicescu (2016) evaluated the influence of orientation on cooling and heating requirements in a greenhouse (180 m^2) in Romania. The study reported that for an EW oriented greenhouse a reduction in energy used for cooling of about 125 kW h d^{-1} may be achieved in June, while 87 kW h d^{-1} of energy for heating may be saved in January, compared to an NS oriented greenhouse. Ahamed et al. (2018a) used a heating simulation model to explore which greenhouse design parameters, including orientation are crucial for reducing heating demand in high northern latitudes. The study reported a significant improvement in energy performance for EW oriented greenhouses.

FF

The orientation of an FF plays a crucial role in maximising sunlight transmission to the cultivation space as well as to the interior of a building accommodating these uses, where sunlight availability is essential. While the south elevation receives the highest portion of solar radiation (e.g. Albatayneh, Mohaidat, Alkhazali, Dalalah, & Bdour, 2018), this location on a building's envelope is seen as the most advantageous for implementing an FF in terms of the portion of solar radiation received (US 8,151,518 B2, 2012; Jenkins, 2018). Using simulation software, Jenkins (2018) was able to determine whether double-skinned façades would be able to support plant growth under UK climatic conditions. The study reported that it would be possible to cultivate crops in an FF facing any direction during summertime. However, none of the orientations would gain the minimum energy required without artificial lighting support during winter months.

PFSL/VF

When making design decisions on the selection of an architectural form for CEA, its orientation plays a crucial role in maximising sunlight transmission to the interior. It was revealed that the buildings which receive the highest portion of solar radiation are those with their long axis facing north/south (e.g. Albatayneh et al., 2018). The research conducted by Jenkins (2018) revealed that when up-cycling buildings for a PFSL, the location of growing installations along east, south and west glazed façades is beneficial, as these orientations allow productive crop growing (Jenkins, 2018). In the study, north-facing façades were considered as *additional growing space* (Jenkins, 2018, p. 314) where food cultivation may not be efficient, especially during winter months.

PFAL

While repurposing urban structures for a PFAL, the orientation of a building does not play any role in crop cultivation or energy efficiency in this type of building-based farming. CEA lit solely by artificial lighting sources may be beneficial in high-density cities, where sunlight availability and shading by surrounding building blocks constrain the up-cycling of buildings for farming relying on natural light.

4.3.3. Cladding materials to enclose a space for controlled environment agriculture

RTG

Light transmission and thermal insulation parameters are critical attributes when selecting cladding materials for a greenhouse cover. Montero et al. (2017) summarised materials which are applicable for this type of structures in various European locations and evaluated their advantages and limitations (Appendix B). The study revealed that glass and semi-rigid plastics, such as Polycarbonate (PC) or Polymethacrylate (PMMA), are characterised by excellent light transmittance and therefore excellent for urban applications. Glass additionally excels due to good heat retention, which benefits the energy efficiency of the agricultural system developed (Papadakis et al., 2000). Single-layered materials benefit the internal environment with higher light transmission, where double layer panels constrain light transmission up to 10 percent (Montero et al., 2017). Moreover, the application of diffusive glass could bring potential energy savings due to improved light transmission, which results in the reduced need for supplemental lighting (Ahemd, Al-Faraj, & Abdel-Ghany, 2016; García Victoria et al., 2012; Hemming et al., 2017).

FF

The material theoretically considered for the envelope of an FF is glass. Three proposals for FFs identified in the literature review (US 8,151,518 B2, 2012; Jenkins, 2018; Stec et al., 2005) discuss the benefits of this material for plant cultivation, sunlight transmission and the thermal performance of the accommodating building. For instance, when building a prototype of his FF, Jenkins (2018) used a full-scale VS-1 façade system provided by Glassolution. Other available glazing materials (e.g. ETFE foil) have not been analysed yet.

PFSL/VF

When retrofitting buildings, the existing cladding materials should be retained. This approach to redundant building stock is considered a principle of sustainable urban development, where energy embodied in existing buildings and used materials are not wasted and replaced with new products (Lehmann, 2010b). While a PFSL relies on sunlight, it is crucial for maximising glazed surfaces for increasing the productivity and resource efficiency of the farm (Despommier, 2010; Jenkins, 2018). However, there is a relatively small body of literature that is concerned with the glazing material to be applied when up-cycling buildings for a PFSL. The general guiding document *Glazing at height* (Keiler, Walker, Ledbetter, & Wolmuth, 2005) advocates the use of insulated glass units and ETFE foil (ethylene tetrafluoroethylene) for architectural applications which require internal environmental control. In Irwell House, repurposed for a PFAL, glass was the existing cladding material which benefitted plant growth (Jenkins, 2018). In his research on VF, Despommier (2011b) suggested using ETFE cushions for the skin of a building, due to the transparency and self-cleaning properties of this material. Glass and ETFE foil are recommended for urban applications owing to the aesthetic benefits (Despommier, 2011; Keiler et al., 2005).

PFAL

Existing cladding materials are crucial considerations when selecting a building to be adaptively reused for a CEA operation, as they have a significant impact on the energy use for heating, cooling and ventilation (Stanghellini et al., 2016). Using existing materials is recommended for the adaptive reuse process from an environmental perspective, as such an approach prevents embodied energy loss and the generation of demolition waste (Lehmann, 2010b). For developing an energy-efficient PFAL, Kozai (2013) recommended utilising a *thermally well-insulated and nearly airtight warehouse-like structure covered with opaque walls* (Kozai, 2013, p. 448). Existing PFALs are often located in industrial buildings, warehouses and thermally insulated shipping containers. However, the research to date has not distinguished any specific materials for PFALs.

4.3.4. Structure of the building up-cycled for controlled environment agriculture

There is a relatively small body of literature that is concerned with the role of the structure of a building in adaptive reuse for CEA. Several studies indicated the arrangement of structural elements and their load-bearing capacity as basic units of analysis when repurposing urban structures for CEA (Jenkins, 2018; Kozai, 2016; Sanyé-Mengual, 2015; Tomlinson, 2015). Sanyé-Mengual (2015) developed a guiding tool for investigating the adaptive reuse potential of rooftops of industrial buildings for RTGs. The efficient structural capacity of the roof was the technical criteria which should be met to accommodate an RTG. Different studies showed that the construction of the greenhouse influences the scale of the CEA operation. Although a single-span greenhouse generates lower initial costs related to its implementation in comparison to a multi-span system (Djevic & Dimitrijevic, 2009; Hanan, 2017), the structure of the multi-span greenhouse offers the potential for maximising the cultivation space (Ahamed et al., 2018a; Djevic & Dimitrijevic, 2009; Hanan, 2017; Sethi, 2009). The study conducted by Jenkins (2018) revealed that the structural capacity of a building, as well as the distances between slabs, columns and load-bearing walls, affected the vertical and horizontal multiplication of growing units and the height of tiers, thus influencing the scale and productivity of the implemented PFSL. The research highlighted the load-bearing capacity of the external structure of a building as a possible limitation for implementing an FF. When investigating the up-cycling potential of abandoned industrial buildings for a PFAL, Tomlinson (2015) highlighted the high potential of this architectural type for CEA due to its load-bearing capacity and sizeable internal space with minimal structural elements. Similarly, Kozai (2016) indicated these two structural features of industrial buildings as beneficial for accommodating a PFAL. Taken together, these studies revealed the significant role of analysing the structural elements of an existing building for recognising structural opportunities and limitations for the initial adaptive reuse design scenario development.

Table 8: Summary of the crucial architectural considerations for the adaptive reuse of buildings for CEA

TYPE	ARCHITECTURAL FORM	APPLICABLE	AUTHOR	ADVANTAGES
RTG	Single-span greenhouse	Yes	Djevic & Dimitrijevic, 2009; Hanan, 2017	Lower initial costs related to the construction of a greenhouse;
	Uneven-span shape greenhouse	Yes	Sethi, 2009; Ahamed et al., 2018;	Maximised solar radiation transmission; The highest internal air temperature among all shapes;
	Quonset shape greenhouse	Yes	Sethi, 2009; Çakir & Şahin, 2015; Ahamed et al., 2018	Reduced annual heating requirements compared to uneven-span gable roof shape; Can be built as a single-span greenhouse
	Multi-span greenhouse	Yes	Djevic & Dimitrijevic, 2009; Hanan, 2017	Reduced annual heating requirements compared to single-span greenhouse;
	Uneven-span shape greenhouse	Yes	Sethi, 2009; Ahamed et al., 2018a	Can be built as a multi-span greenhouse; Improved energy efficiency of RTG
	Length-width ratio > 1 Roof angle 25°-30°	Yes	Ahamed, et al., 2018a	Improved energy efficiency of RTG
FF	Cavity between the layers of a double-skin façade	Yes	Stec et al., 2005; US 8,151,518 B2, 2012; Jenkins, 2018	Improved energy-efficiency of the accommodating building
PFSL	Existing building	Yes	Despommier, 2011a; Thomaier et al., 2014; Chance et al., 2018; Jenkins, 2018	Reduced initial investment associated with the construction of a new building; Potential for utilising a roof and façades for locating RTGs and FFs; Social and environmental symbiosis with other uses
PFAL	Existing building			
	Warehouse-like structures	Yes	Kozai, 2013; Tomlinson, 2015; Brown-Paul, 2016; Chance et al., 2018	Flexibility in the interior arrangement; Optimal management of the internal environmental parameters;

TYPE	ORIENTATION (LONGER AXIS)	APPLICABLE	AUTHOR	ADVANTAGES
				Potential for resource use efficiency
	Shipping container	Yes	Tsitsimpelis et al., 2016	Modular farming space; Easy to multiply in urban settings
TYPE	**ORIENTATION (LONGER AXIS)**	**APPLICABLE**	**AUTHOR**	**ADVANTAGES**
RTG	EW	Yes	Chandra, 1976; Papadakis et al., 1998; Dragicevic, 2010; Stanciu et al., 2016; Ahamed et al., 2018a	Maximised solar radiation transmission; Improved energy efficiency of RTG
FF	S Any location in summer months	Yes	US 8,151,518 B2, 2012; Jenkins, 2018	Maximised solar radiation transmission; Improved energy efficiency of FF and the accommodating building
PFSL	NS	Yes	Albatayneh et al., 2018	Maximised solar radiation transmission; Eluded main wind stream
	Growing installations located along east, south and west facades	Yes	Jenkins, 2018	Maximised solar radiation transmission
PFAL	-	No	-	-
TYPE	**CLADDING MATERIAL**	**APPLICABLE**	**AUTHOR**	**ADVANTAGES**
RTG	Glass	Yes	Swinkels et al., 2001; Ahemd, Al-Faraj, & Abdel-Ghany, 2016; García Victoria et al., 2012; Hemming et al., 2017; Montero et al., 2017; Semple et al., 2017; O'Hegarty et al., 2016	Good solar radiation transmission; Good heat retention; Low transmission of UV light; Durability (long lifespan); Low maintenance costs; Possible integration with a PV system
	Semi-rigid plastics: Polycarbonate (PC)	Yes	Fabrizio, 2012; Stanghellini et al., 2016; Montero et al., 2017	Good solar radiation transmission; Lightweight; Fire-law-compliant; Impact resistance; Hail resistance
	Polymethacrylate (PMMA)	Sidewalls only. Under fire, it melts and drips	Stanghellini et al., 2016; Montero et al., 2017	Good solar radiation transmission; UV filter (300 nm); Strong and lightweight; High corrosion resistance
	Plastic films Polyvinylchloride (PVC)	Yes	Montero et al., 2017	Strong and lightweight; High resistance; Does not propagate flames

	PE-based films (multilayer)	Sidewalls only. Under fire, it melts and drips	Cemek et al.,2006; Montero et al., 2017; Ahamed et al., 2018b	Legally compliant only for walls; Low infiltration rate; Fair distribution of the transmitted light; Strong and lightweight; High resistance; Cheap
	Ethylene Tetrafluoroethylene Copolymer (ETFE)	Yes	Robinson-Gayle et al., 2001; Montero et al., 2017	Fire-law compliant; Long lifespan; Lightweight; Fair distribution of transmitted light; UV filter; High corrosion resistance; High melting temperature; Flexible; Good solar radiation transmission
	Acrylic panel	Yes	Papadakis et. al., 2000	Good solar radiation transmission; Cheap
FF	Glass	Yes	Stec et al., 2005; US 8,151,518 B2, 2012; O'Hegarty et al., 2016; Jenkins, 2018	Good solar radiation transmission; Good heat retention; Low transmission of UV light; Durability (long lifespan); Low maintenance costs
PFSL	Existing cladding material	Yes	Lehmann, 2010; Stathopoulos et al., 2018	Environmental benefits associated with the adaptive reuse of buildings: energy savings and utilising existing materials; Good rating for insulation
	Glass	Yes	Robinson-Gayle et. al., 2001; Keiler et al., 2005; Peng et. al., 2011; Jelle et al., 2012; Lai & Hokoi, 2015; O'Hegarty et al., 2016	Good light transmittance; Good heat retention; Good acoustic performance; Low transmission of UV light; Durability (long lifespan); Low maintenance costs
	Ethylene Tetrafluoroethylene Copolymer (ETFE)	Yes	Robinson-Gayle et al., 2001; Keiler et al., 2005; Despommier, 2011; Lau et al., 2016; Hu et al., 2016	Fire-law compliant; Long lifespan; Lightweight; UV filter; High corrosion resistance; High melting temperature; Flexible; Good light transmittance; Good heat retention

PFAL	*Thermally well-insulated and nearly airtight warehouse-like structure covered with opaque walls (Kozai, 2013, p. 448)*	Yes	Kozai, 2013; Stathopoulos et al., 2018	Environmental benefits associated with the adaptive reuse of buildings: energy savings and utilising existing materials; Good rating for insulation
	Thermally insulated shipping container	Yes	Tsitsimpelis et al., 2016	High rating for insulation

TYPE	STRUCTURE	APPLICABLE	AUTHOR	ADVANTAGES
RTG	Multi-span	Yes	Djevic & Dimitrijevic, 2009; Sethi, 2009; Hanan, 2017; Ahamed et al., 2018a	Larger distances between structural elements allow maximum crop cultivation area
	Structure of the roof	Yes	Sanyé-Mengual, 2015	Efficient load-bearing capacity to accommodate RTG
FF	Double glazed façade	Yes	Jenkins, 2018	Efficient load-bearing capacity to accommodate an FF
PFSL	Existing structure	Yes	Tomlinson, 2015; Jenkins, 2018	Larger distances between structural elements allow maximum crop cultivation area
PFAL	Existing structure	Yes	Tomlinson, 2015; Kozai, 2016	Larger distances between structural elements allow maximum crop cultivation area

4.4. Resource and energy-efficient technologies and alternative energy technology options for controlled environment agriculture

The pressing concerns of high resource- and energy-use by CEA significantly limits the implementation of these productive systems (Ackerman et al., 2013; Graamans et al., 2017; Kozai, 2013). This challenge is particularly problematic in an urban context. With the growing urban population (United Nations, 2018) and rising energy demand (OECD, 2018), cities are continuously transforming to accommodate new infrastructure, which reduces the high environmental impacts associated with building construction and operation. While building-based CEA is seen as a potential contributor to the food self-sufficiency of urban areas (e.g. Jenkins, 2018; Sanyé-Mengual, 2015), the vision of how to effectively manage the system to benefit resource- efficiency is still uncertain (Ackerman et al., 2013; Romeo, Vea, & Thomsen, 2018; Tsitsimpelis et al., 2016). CEA is a fusion of plant science, engineering and environmental control technologies used to optimise plant growing conditions, plant quality and productivity (Ackerman et al., 2013). The proper design and operation of this system can reduce adverse environmental impacts (Kozai, 2013). Applying resource-efficient technologies and alternative energy technology options is now seen as a way to justify the use of urban buildings for CEA (Ackerman et al., 2013; Al-Chalabi, 2015; Romeo et al., 2018). The summary of the literature review conducted in this section on the resource-efficient technologies and alternative energy technology options for the adaptive reuse of buildings for CEA is presented in Table 9.

4.4.1. Water-saving and recycling

The water-saving and recycling potential of CEA is associated with the application of technologically advanced food cultivation systems and the development of synergies between them and their accommodating or neighbouring buildings (Ackerman et al., 2013; Specht et al., 2013). When linking these systems, technologies for recycling water resources and rainwater storage may be applied and further supported by water-efficient installations. Gould & Caplow (2012) generally stated that each hectare of hydroponic crop cultivation might save, on average, 74,000 tons of fresh water per year. However, the reduction in water use in CEA varies depending on the soilless crop cultivation technique analysed and its application. When analysing hydroponics, it is estimated that the open system loses about 25 percent of water in each cycle. Significant water savings are obtained when a closed hydroponic system is applied. The highest water efficiency is associated with the NTF hydroponic technique, where water with nutrient solution is constantly circulating due to the location on a slope (Putra & Yuliando, 2015). Another opportunity is identified when using regenerated alternative freshwater sources, which can be applied to CEA as grey and saline water. These resources can be recycled from the building and the surrounding urban environment (Specht et al., 2013). Adequate clarification such as sterilisation and filtration allows the reuse of these resources for irrigation purposes (Ellingsen & Despommier, 2008). Greywater regeneration for CEA is now a common practice (e.g. the Maison Productive in Montréal), however creating water reuse synergies between the accommodating building and urban agriculture requires further research with this area (Specht et al., 2013).

Another opportunity for water-saving and recycling is seen in rainwater harvesting, which is now widely practised when developing Z-Farming (Thomaier et al., 2014). When implementing RTGs in New York (USA), rainwater collection and reuse systems are obligatory for gaining planning benefits regarding the exclusion of an RTG from the Floor-to-Area Ratio (Ackerman et al., 2013). This expectation is mainly borne out with significant water savings associated with the reuse of rainwater for CEA. For instance, Sanyé-Mengual (2015) analysed rainwater harvesting opportunities on rooftops in retail parks repurposed with i-RTGs with a hydroponic system in six different European locations: Sant Boi and Montigalà, Spain, Alfragide, Portugal, Utrecht and Rotterdam, the Netherlands and Berlin, Germany. The study revealed that when developing RTGs together with rainwater harvesting systems, the plant water requirements could be satisfied in five of the locations explored. Therefore, the design proposals for up-cycling buildings for CEA should consider all identified water-saving and recycling systems.

4.4.2. Energy-saving systems

Minimising the input energy of building-based UF is a crucial consideration when making design decisions regarding the development of all investigated forms of CEA (e.g. Ackerman et al., 2013; Toyoki Kozai et al., 2015; Romeo et al., 2018; Sanyé-Mengual, 2015). A great deal of previous research into the resource demands of CEA and alternative energy technologies has focused on RTGs, PFSLs, PFALs and VF. In the case of RTGs located in the temperate climatic zone, increased energy demand is associated with fan-induced ventilation, heating and cooling technologies. In PFSLs and PFALs energy demand is considered higher than in RTGs due to the need for further energy-dependent technologies caused by developing high-density crop production in limited volume and without natural ventilation (Graamans et al., 2017). Artificial illumination, cooling, ventilation, dehumidification and heating installations were determined as the systems with the highest energy requirements in PFSLs and PFALs (Graamans et al., 2017; Kozai, 2013).

In RTGs, energy-saving benefits are gained when implementing technologies developed for rural and urban applications (Pons et al., 2015). Findings from research focused on rural greenhouses recommend using closed or semi-closed greenhouses (Cerón-Palma et al., 2012; Sanjuan-Delmás et al., 2018). The closed greenhouse design assumes no windows to cool the interior or to release excess humidity, while in the semi-closed greenhouse, some exchange of air between the internal and the external environment is maintained. Instead of natural ventilation, mechanical means of cooling are employed in both systems. The excess heat gained inside the greenhouse is stored in long- and/or short- term thermal storage systems (De Gelder, Dieleman, Bot, & Marcelis, 2012). Closed and semi-closed greenhouses are recommended for urban application as less-input and low-emission RTGs (Cerón-Palma et al., 2012; Sanjuan-Delmás et al., 2018).

The existing literature on energy-efficient systems for RTGs extensively focuses on creating a synergic relationship between RTGs and the building upon which the greenhouse is located, which is named an i-RTG. The total heating requirements of i-RTGs can be reduced when utilising the waste heat from the building, and this building may use excess heat produced in the i-RTG due to solar gains during cold but sunny days. Additionally, the exchanges of air between different facilities offer the possibility for the reuse of CO_2 and O_2 (Delor, 2011). In a preliminary study, Delor (2011) quantified that when developing the synergic exchange of heat between a building and an RTG, up to 41 percent of energy for heating the building may be saved. In the research project Fertilecity, Pons et al. (2015) applied Building Energy Modeling software to assess potential energy savings derived from the development of an i-RTG on the rooftop of the university building in Bellaterra, Spain. The study reported higher temperatures at night time in the i-RTG due to thermal synergies with the building underneath when compared with conventional RTGs. The benefits of such a heat exchange are explored regarding existing i-RTGs. For instance in New York, Nelkin and Caplow (2008) operate a 120 m^2 i-RTG, which works independently from urban power resources. Nevertheless, the waste heat exchange is associated with technical challenges, primarily related to the integration of i-RTG climate control technology with the HVAC system of the pre-existing building (Ackerman et al., 2013).

Apart from local food cultivation, the reduced energy demand of a building with an integrated FF is the main benefit theoretically considered for this system. Plants growing in a cavity between the double skin façade serve as blinds, thus contributing to the reduced cooling requirement (Stec et al., 2005). Stec et al. (2005) built a simulation model of an FF to explore if plants may improve the indoor climate and allow energy savings. The study reported a reduction in cooling requirements of almost 20 percent. A similar result was quantified for the energy demand of the cooling installation. Potentially higher energy savings may arise from the synergy between the building and the FF designed and built by Jenkins (2018). Using energy simulation software, it was quantified that the winter heating demand of adjacent spaces could be reduced by 40 percent in winter, and the summer cooling demand by 70 percent. Additionally, in the case of naturally ventilated buildings, an FF reduces the operation period of ventilation during warm months and increases the operation period during cold months. This conclusion offers further potential energy savings derived from the synergic relationship developed (Stec et al., 2005).

Technology options, which enable the effective and efficient use of energy in PFSLs and PFALs are improved electric devices, exceptionally energy-efficient pumps and boilers (Ahamed et al., 2018b), solid-oxide fuel cells (Kikuchi, Kanematsu, Yoshikawa, Okubo, & Takagaki, 2018; Kikuchi et al., 2018; Semple, Carriveau, & Ting, 2017) and energy-efficient lighting (LED) (Bantis, Ouzounis, & Radoglou, 2016; Kozai, 2016; Matsuda, Yamano, Murakami, & Fujiwara, 2016; Singh, Basu, Meinhardt-Wollweber, & Roth, 2015; Yeh & Chung, 2009). Over the past decade, most research has emphasised the use of LEDs as the energy-efficient artificial lighting source for PF (Bergstrand, Mortensen, Suthaparan, & Gislerød, 2016; Hernández, Eguchi, Deveci, & Kubota, 2016). Reduced energy use associated with the utilisation of LEDs is related to the low radiant heat output of this lighting source in comparison with hot, high-intensity discharge emitters, which require more electricity while generating heat. LEDs can be located close to plant tissues and for that reason, they operate at lower energy levels to initiate the processes needed for the plant growth (Massa, Kim, Wheeler, & Mitchell, 2008; Poulet et al., 2014). These facts contribute to the reduction of energy consumption of LEDs up to 70 percent in comparison with traditional lighting sources (Singh et al., 2015). Although the initial implementation costs of the LED system in CEA are considered higher than other lighting sources, the energy savings minimise electricity costs, and the initial investment is expected to be returned over long-term operation (Singh et al., 2015). Moreover, Kozai (2016) claims that LEDs will become the primary artificial lighting source in next-generation urban agriculture, and as main arguments for this scenario, describes the optimisation of the electricity-to-light energy conversion factor and implementation of renewable energy sources as a way of reducing the cost of electricity.

For all CEA systems mentioned, significant energy savings can be achieved by carefully managing indoor microclimate, especially when optimising air temperature and relative humidity (Ahamed et al., 2018b; Caplow & Nelkin, 2007; Hemming et al., 2017; Kozai, 2013; Kozai et al., 2015; Thomaier et al., 2014; Van`t Ooster et al., 2008). For instance, the implementation of a system for temperature integration inside a greenhouse can reduce heating loads by about 10-25 percent (Ahamed et al., 2018b). For humidity control in cold regions, the use of a mechanical dehumidifier allows energy savings and increased effectiveness for year-round operation (De Zwart, 1996; Gao, 2012).

4.4.3. Alternative energy technology options

Alternative energy technology options considered for building-based CEA include photovoltaic panels (PV), wind power systems and installations which enable the use of waste heat, geothermal energy and biomass. The implementation of all of these technologies requires decisions to be made already at the planning and design stages. PV and wind power systems affect the appearance of the accommodating building, thus influencing the aesthetics of the urban environment.

Solar power systems

PV panels are a renewable energy technology, which are widely used in cities and rural agriculture despite the relatively high initial investment being considered the primary constraint (Allardyce, Fankhauser, Zakeeruddin, Grätzel, & Dyson, 2017). When implemented as building-integrated photovoltaics (BIPV) they replace parts of the outer envelope, for instance a façade, roof or skylights (Lehmann, 2010b). BIPV is recommended for PF (Despommier, 2010). The key benefits of this system are seen in the generation of passive energy as a contribution to the building's self-sufficiency (e.g. Hestnes, 2002; Hu et al., 2016; Jelle et al., 2012; Mandalaki, Zervas, Tsoutsos, & Vazakas, 2012). BIPV offers opportunities for architectural design, particularly for improving the aesthetics of existing buildings (e.g. Hestnes, 2002; Jelle et al., 2012). Various PV-integration options (Fig. 30) are possible due to the availability of numerous photovoltaic products including foil, tile and module elements, as well as solar cells glazing materials and building attached PV systems (Hestnes, 2002; Jelle et al., 2012).

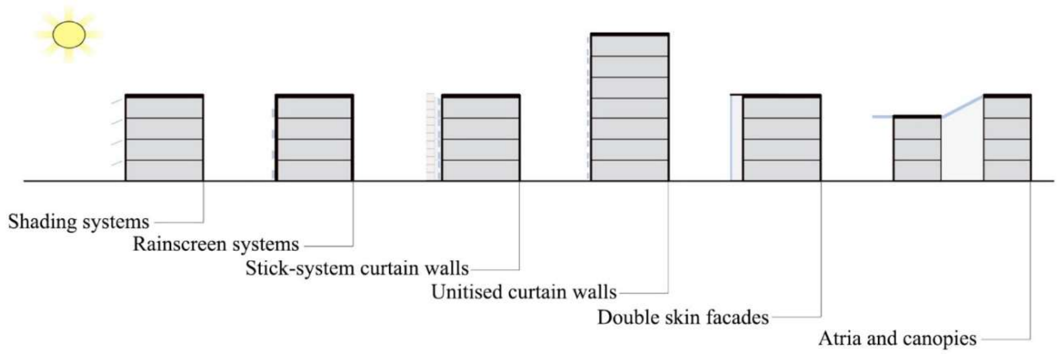


Figure 30: PV-integration options. Adapted from Roberts & Guariento, 2009

Greenhouse-integrated photovoltaics (GIPV) known as *agrivoltaics* (Dupraz et al., 2011), are installed as a replacement for an element of external cladding (Allardyce et al., 2017). The materials selected for the greenhouse envelope are required to be transparent. Thus several materials were proposed to develop GIPV, including Dye-Sensitized Solar Cells and organic PVs (Allardyce et al., 2017). These systems potentially offer new application opportunities and provide additional advantages, for instance reduced energy use and better crop quality, however they need further improvements to benefit these features (Allardyce et al., 2017; Amaducci, Yin, & Colauzzi, 2018). Another innovative solar energy system was developed by Allardyce, Fankhauser, Zakeeruddin, Grätzel, & Dyson (2017), who proposed semi-transparent photovoltaics as greenhouse glazing, which benefits the agricultural operation with thermal stabilisation and similar or improved edible biomass yields. The best results regarding energy generation are achieved when low tilt-angle modules are installed inside the roof of a greenhouse, which is north-south oriented (Miyamoto et al., 2009).

Wind power systems

The utilisation of wind power systems for PF within cities was proposed by Despommier (2010). In urban settings, wind environments differ considerably from those in rural or suburban areas. The surface roughness caused by urban arrangements modifies the wind speed. Components which affect urban aerodynamics include building geometry, configuration, the spacing of buildings, and urban greenery (Stathopoulos et al., 2018). Implementation opportunities to utilise wind as an energy source for CEA are offered by the upper air, as this area is not affected significantly by surface roughness. Moreover, three-dimensional urban arrangements developed, such as urban canyons, often cause strong winds between neighbouring structures and offer a potential implementation space for an efficient wind power system (Delucchi & Jacobson, 2011). Therefore, existing urban arrangements need to be analysed before the specific wind power system and its location are selected in order to make design decisions that will maximise its efficiency for CEA.

Industrial waste heat exchange

Creating synergies between the existing building and its various uses with CEA offers the potential for industrial waste heat exchange as a method for saving energy (Sanjuan-Delmás et al., 2018; Specht et al., 2013; Togawa et al., 2014). This technology has the potential to be applied to all building-based CEA typologies. However, the technology is still in the early stages of development (Sanjuan-Delmás et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2013). Current research on utilising industrial waste heat for CEA operations focuses on i-RTGs (Sanjuan-Delmás et al., 2018) and PF (Kikuchi, Kanematsu, Ugo, Hamada, & Okubo, 2016; Togawa et al., 2014).

A life cycle assessment of the i-RTG constructed on a building (office, laboratories) of the Universitat Autonoma de Barcelona campus (Spain) was conducted by Sanjuan-Delmás et al. (2018). The results revealed that during winter months, the internal environment of the i-RTG benefits from warm air from the accommodating building, causing milder temperatures. The higher internal temperatures in winter optimise the growing conditions and reduce the necessity for heating. To achieve similar temperatures in a greenhouse implemented on the ground 341.9 kWh of thermal energy/m^2/year are required, which contributes to the generation of between 5.5 and 113.8 kg CO_2 eq/m^2/year depending on the type of fuel and heating system used (Nadal, Llorach-Massana, et al., 2017). This heating increases the carbon footprint of food production by several times compared to the i-RTG.

The exchange of industrial waste heat is a practice proposed for PF (Togawa et al., 2014). This kind of industrial symbiosis was analysed by Kikuchi et al. (2016), who explored the possible exchange of bagasse-derived unused heat produced in a sugar mill with surrounding buildings. Similarly, Togawa et al. (2014) developed a simulation process model, which integrates spatial analysis, land use controls and technology systems in order to maximise the use of waste heat produced in coal-fired thermal power plants in nearby plant factories. The results revealed that when the system is applied, more than 50 percent of CO_2 emissions may be cut. However, the study indicated the need for new and developing technologies, which offer more efficient waste heat recovery and include non-traditional sources.

Geothermal energy

The use of geothermal energy is recommended for urban areas as alternative energy for heating (e.g. Eicker & Klein, 2014; Unternährer, Moret, Joost, & Maréchal, 2017). Utilising this energy source has been widely studied for agricultural applications located in rural areas, especially for soil-based geothermal supported greenhouses (e.g. Ahamed et al., 2018a; Çakir & Şahin, 2015;

Fabrizio, 2012). In the case of building-based CEA, geothermal energy is considered an alternative energy source for RTGs (Sanyé-Mengual, 2015), VFs (Despommier, 2010; Shamshiri et al., 2018) and PF (Ting et al., 2016; Togawa et al., 2014). These recommendations were made theoretically, and assume existing technology to be applicable when locating CEA in urban areas (Ting et al., 2016).

Biomass

The utilisation of biomass as a by-product of plant-derived production is a way to reduce the environmental impact of UF in a controlled environment (e.g. Kikuchi et al., 2016; Nadal et al., 2017). This technology is theoretically considered an alternative energy source for heating RTGs (Nadal, Llorach-Massana, et al., 2017) and PF (Kikuchi et al., 2018). More detailed analysis of this passive energy source was conducted for soil-based greenhouses. For instance, the comparative investigation of various heating options, including a natural gas boiler, wood biomass and a solar assisted vertical ground-source heat pump revealed that utilising wood biomass represents the most sustainable heating system among the case studies analysed (Hepbasli, 2011).

Table 9: Summary of the resource-efficient technologies and alternative energy technology options for the adaptive reuse of buildings for CEA

TYPE	TECHNOLOGY	AUTHOR
WATER SAVING AND RECYCLING	Closed-loop plant cultivation system	Gould & Caplow, 2012; Putra & Yuliando, 2015
	Regenerating alternative freshwater sources	Ellingsen & Despommier, 2008 Specht et al., 2013
	Rainwater harvesting	Ackerman et al., 2013; Thomaier et al., 2014; Sanyé-Mengual, 2015
ENERGY SAVING	Closed or semi-closed greenhouses	Cerón-Palma et al., 2012; De Gelder et. al., 2012; Vadiee & Martin, 2012; Sanjuan-Delmás et al., 2018
	Synergies between UF and the accommodating building	Specht et al., 2013; Thomaier et al., 2014; Sanyé-Mengual, 2015
	Heat exchange	Delor, 2011; Pons et al., 2015; Nelkin and Caplow, 2008
	Reuse of CO_2 and O_2	Delor, 2011
	FF for cooling the building in summer and heating in winter	Stec et al., 2005; Jenkins, 2018
	Energy-efficient electric devices	
	Energy efficient pumps and boilers	Ahamed et al., 2018b

	Solid-oxide fuel cell	Semple et al., 2017; Kikuchi et al., 2018
	LED lighting	Barta et al., 1992; Yeh & Chung, 2009; Singh et al., 2015; Bantis et al., 2016; Bergstrand et al., 2016; Hernández et al., 2016; Kozai, 2016; Matsuda et al., 2016
	Optimal management of indoor microclimate	Caplow & Nelkin, 2007; Van`t Ooster et al., 2008; Kozai, 2013; Thomaier et al., 2014; Kozai et al., 2015; Hemming et al., 2017; Ahamed et al., 2018b
ALTERNATIVE ENERGY TECHNOLOGY OPTIONS	BIPV	Despommier, 2010
	GIPV	Miyamoto et al., 2009; Dupraz et al., 2011; Allardyce et al., 2017; Amaducci et al., 2018
	BIWT	Despommier, 2010
	Industrial waste heat exchange	Specht et al., 2013; Togawa et al., 2014; Kikuchi et al., 2016; Nadal et al., 2017; Sanjuan-Delmás et al., 2018
	Geothermal energy	Despommier, 2011; Fabrizio, 2012; Togawa et al., 2014; Çakir & Şahin, 2015; Sanyé-Mengual, 2015; Ting et al., 2016; Ahamed et al., 2018a; Shamshiri et al., 2018
	Biomass	Hepbasli, 2011; Kikuchi et al., 2016; Nadal et al., 2017; Kikuchi et al., 2018

4.5. Case study analysis

The exploratory case study research presented in this section aims to explore the development and operation of the building-based CEA practices through the planning, architectural and environmental framework that arose from the literature review. The aim of this investigation is to validate the theoretical findings from the literature analysis conducted in the first part of this chapter and complement this knowledge with the primary data. To achieve this goal, three existing building-based CEA operations have been strategically chosen: Grow Bristol (Fig. 31), Biospheric Project (Fig. 32) and BIGH Ferme Abattoir (Fig. 33). The introduction to these urban farms and their selection criteria is included in Chapter 2, section 2.8.

Figure 31: Grow Bristol, Bristol, UK, The shipping container that accommodates hydroponics. Photo: Szopinska-Mularz 2018

Figure 32: The Biospheric Project, Irwell House, Salford, UK, The building and RTG. Photo: Jenkins 2018

Figure 33: BIGH Ferme Abattoir, Brussels, Belgium, Foodmet market hall with RTG. Photo: Lateral Thinking Factory 2018

4.5.1. Planning exploration of case studies

Table 10: Summary of the planning analysis of urban farms selected for the case study research

	UF		
BENEFITS	Grow Bristol	Biospheric Project	BIGH Ferme Abattoir
SOCIAL	Improved transparency of food production; Connection between consumers and food production; Improved consumer awareness; Improved food quality; Educational opportunities; Spaces for experiments and creativity	Improved transparency of food production; Connection between consumers and food production; Improved consumer awareness; Improved food quality; Nutrition-related health outcomes (e.g. diabetes); Improved community food security; Educational opportunities; Community building (empowerment, fun); Spaces for experiments and creativity; Improved living quality	Improved transparency of food production; Connection between consumers and food production; Improved consumer awareness; Improved food quality; Educational opportunities

ENVIRONMENTAL	Reduced emissions and transport (food miles); Improved organic waste recycling; Reduced pressure on agricultural land; Increased horticultural yields	Reduced emissions and transport (food miles); Improved organic waste recycling; Improved water use efficiency; Carbon and contamination fixation; Reduced pressure on agricultural land; Sustainable architecture and urban landscape; Increased horticulture yields; Enhanced closed cycles	Reduced emissions and transport (food miles); Improved organic waste recycling; Improved water use efficiency; Improved building energy efficiency; Carbon and contamination fixation; Reduced pressure on agricultural land; Sustainable architecture and urban landscape; Increased horticultural yields; Enhanced closed cycles
ECONOMIC	Adaptive reuse of derelict buildings and spaces; Reduction of costs related to conventional agriculture; Local economic development; Potential products and high yields; New business models, income and employment; Innovation to attract investors and showcase; New marketing opportunities (e.g. new labels); Availability of financial aid for new products; Improved regional value chains	Adaptive reuse of derelict buildings and spaces; Reduction of costs related to conventional agriculture; Potential products and high yields; Innovation to attract investors and showcase; New marketing opportunities (e.g. new labels); Availability of financial aid for new products; Improved regional value chains	Adaptive reuse of derelict buildings and spaces; Reduction of costs related to conventional agriculture; Local economic development; Potential products and high yields; New business models, income and employment; Innovation to attract investors and showcase; New marketing opportunities (e.g. new labels); Availability of financial aid for new products; Improved regional value chains
TECHNICAL	Improved urban self-sufficiency; Adaptive reuse of buildings;	Improved urban self-sufficiency; Adaptive reuse of buildings; Experience in greenhouses and climatic architecture;	Improved urban self-sufficiency; Adaptive reuse of buildings; Experience in greenhouses and climatic architecture; Energy-efficient productive architecture

AESTHETIC	Improved city landscapes	Improved building aesthetics	Improved building aesthetics
PARTNERSHIP AND POLICIES	Improved public awareness; New institutional supports and policies instituted for UA; New inter-divisional, inter-governmental and/or cross-sectoral collaborations	Improved public awareness; New institutional supports and policies instituted for UA; New inter-divisional, inter-governmental and/or cross-sectoral collaborations	Improved public awareness; New institutional supports and policies instituted for UA; New inter-divisional, inter-governmental and/or cross-sectoral collaborations

This investigation (Table 10) confirms that the identified drivers and motivations for the implementation of the analysed UF practices are located within the social, environmental, economic, technical, aesthetical, partnership and policy domains of the urban development.

4.5.2. Architectural exploration of case studies

Table 11: Summary of the architectural analysis of urban farms selected for the case study research

UF	TYPE	ARCHITECTURAL FORM	ORIENTATION	CLADDING MATERIAL	STRUCTURE
Grow Bristol	PFAL	Shipping container	Not applicable	Thermally insulated metal or composite panels	Structure of two existing shipping containers
Biospheric Project	PFSL	Existing building	NW/S	Existing material	Structure of the existing building
	RTG	Quonset shape greenhouse on the existing building	NW/S	PE-based film	Single-span
BIGH Ferme Abattoir	RTG	Even-span, L-shape greenhouse on the existing building	NE/SW NW/SE	Glass	Multi-span

	URBAN APPROACH	ARCHITECTURAL APPROACH			
	The implementation of building-based farming in cities is continuously challenged by the continuity of urban change and the need for new mixed-use typologies. Proposals for CEA are evaluated regarding economic, environmental and social benefits. CEA is often implemented in obsolete buildings or derelict lots as a meanwhile lease before more advantageous investment will be developed.	**ARCHITECTURAL FORM FOR CEA** The challenges posed by the compact urban environment resulted in the distinction of low-space or no space food cultivation techniques: ZFarming (Specht et al., 2013), BIA (Caplow & Nelkin, 2007) and VF (Despommier, 2011a). Repurposing urban structures for CEA can be done by converting an interior of a building for a plant factory (PF) with sunlight (PFSL) or artificial light (PFAL) (Kozai et al., 2015) as well as utilising a building envelope by developing a rooftop greenhouse (RTG) (Montero et al., 2017; Sanyé-Mengual, Cerón-Palma, et al., 2015) or integrating a façade farm (FF) (US 8,151,518 B2, 2012; Jenkins, 2018)	**ORIENTATION OF AN ARCHITECTURAL FORM FOR CEA** Orientation of an architectural form selected to be repurposed for CEA plays a crucial role in maximising solar energy transmission, which benefits plant cultivation and allows lowering heating loads, thus bringing energy savings and reducing costs of UF operation (Dragicevic, 2010). The decision on the CEA type at the initial stage of the up-cycling design scenario development indicates the lighting source for the food cultivation and impose architectural approach to the functional organisation of the internal space, especially the location of growing units.	**MATERIALS TO ENCLOSE A SPACE FOR CEA** Existing cladding materials are crucial considerations when selecting a building to be adaptively reused for CEA operation as they have a significant impact on the energy use for heating, cooling and ventilation (Stanghellini et al., 2016). Utilising the existing materials is recommended for the adaptive reuse process from the environmental perspective, as such approach prevents embodied energy loss and demolition waste generation (Lehmann, 2010b). Implementing new materials is often needed, especially when developing RTG, FF or PFSL. In such cases, thermal properties, sunlight transmission and architectural quality of the cladding material should be examined before the decision is made.	**STRUCTURE OF THE BUILDING ADAPTIVELY REUSED FOR CEA** Analysing the structural elements of an existing building is crucial for recognising structural opportunities and limitations for the initial adaptive reuse design scenario development for CEA. The structural assessment is required to check the load-bearing capacity of the accommodating architectural form. The existing arrangement of structural elements of the accommodating building is critical for the architectural design of the farming operation. The distance between slabs and columns affects the horizontal and vertical multiplication of growing units, thus influencing the productivity of all analysed CEA typologies.

Figure 34: Architectural analysis of the case studies through the framework that arose from the literature review

The architectural analysis of case studies (Fig. 34, Table 11) revealed that in all cases, the structures chosen for adaptive reuse are located in inner-city areas. This investigation corresponds with the planning phase of the literature review and indicates that such an urban approach offers social, economic and environmental opportunities, which outbalance other urban locations (e.g. peri-urban regions). The benefits include the increased visibility of the farming operation in the inner-city, the proximity to the customers, and shorter product transportation distances (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2015). Therefore, the conceptualisation of the key drivers and motivations has the potential to deliver more robust evidence for accepting CEA as the future use of an inner-city structure when compared to other locations within the city.

The urban farms selected for the case study research represent different architectural approaches to the architectural form which accommodates the productive space. Grow Bristol is developed as a PFAL located in two shipping containers. The Biospheric Project consists of two CEA types, which are a PFSL and an RTG. A PFSL has been implemented within a derelict factory, while an RTG occupies the roof. In the BIGH Ferme Abattoir the productive area is situated in a multi-span RTG.

The investigation into the orientation of the buildings accommodating the case studies showed that in a PFAL, represented by Grow Bristol, the orientation of the structure does not influence design decisions as the CEA operation relies solely on artificial lighting. The longer axis of Irwell House, accommodating a PFSL, is NS located. The hydroponic units were developed along the south, east and north elevations with windows; however, the northern location is designed as an experimental location. The literature review indicated that the NS orientation of the building is optimal for sunlight transmission (Albatayneh et al., 2018), while placing growing installations along the south, east and west elevations is recommended (Jenkins, 2018). The RTG developed on Irwell House as a Quonset shape single-span system is NW/S oriented. In BIGH Ferme Abattoir, an RTG is implemented as even-shape, single-span, L-shape structure, which is oriented NE/SW and NW/SE. The literature review revealed the EW orientation of a greenhouse as the most beneficial due to maximised solar radiation transmission and improved energy efficiency (Ahamed et al., 2018a; Chandra, 1976; Dragicevic, 2010; Papadakis et al., 1998; Stanciu et al., 2016). However, the case study analysis showed that the location of an RTG is a result of a compromise between the beneficial orientation as well as the spatial and structural potential of the roof. Thus, the increased growing area in BIGH Ferme Abattoir or structural capacity of the Irwell House were the crucial design considerations which led to the less advantageous orientation of these RTGs.

The investigation into the external cladding materials revealed that the selection of the urban structure affects the development of the specific typology of building-based CEA. In Grow Bristol, the controlled environment for plant growth was created within the up-cycled shipping container. The outer cladding material does not transmit sunlight to the interior. Thus, the UA operation is developed as a PFAL. The Biospheric Project is located within and upon the obsolete building. The existing windows on the second floor transmit sunlight to the internal area, which brings the opportunity for developing a PFSL. The rooftop potential is used for the location of an RTG as a transparent structure. In BIGH Ferme Abattoir, the CEA operation was implemented on the unoccupied roof of the existing building, which offers high flexibility for selecting the external cladding for CEA. In this case, the architectural approach to up-cycle this area for UF led to the development of an RTG, which maximises sunlight transmission beneficial for plant cultivation. Moreover, the architectural analysis of the case studies revealed that the intended scale of CEA operation affects the selection of the structure with the specific cladding material. The bigger the size of CEA, the higher the requirement for transparent cladding materials. The main reason for this is the lower demand for energy for lighting, which brings environmental benefits associated with minimised reliance on urban resources and resulting economic savings.

Grow Bristol as a PFAL is developed in an up-cycled thermally insulated shipping container, explored by the literature for such applications due to its high rating for insulation (Tsitsimpelis et al., 2016). In the Biospheric Project, a PFAL is implemented in a derelict factory where the existing cladding materials are retained, which provide environmental and economic benefits (Lehmann, 2010). The cladding material for the RTG is PE-based film (Ahamed et al., 2018b; Cemek, Demir, Uzun, & Ceyhan, 2006; Montero et al., 2017). The RTG developed in BIGH Ferma Abattoir is made of glass (Ahemd et al., 2016; García Victoria et al., 2012; Hemming et al., 2017; Montero et al., 2017; O'Hegarty, Kinnane, & McCormack, 2016; Semple et al., 2017; Swinkels, Sonneveld, & Bot, 2001).

The analysis of the structure of the case studies indicates opportunities and limitations relevant to the initial design stage of the adaptive reuse of buildings for CEA. In Grow Bristol, the four walls of the shipping container create the horizontal limitation for locating hydroponic rows, while the height of the structure is the constraint for the vertical multiplication of hydroponic tiers. The existing walls, grid of columns and the distance between slabs on the second floor affect the location of growing units in the derelict factory building (Jenkins, 2018; Tomlinson, 2015) of the Biospheric Project. The structural limitation for the placement of the RTGs of the Biospheric Project and BIGH Ferme Abattoir is the area of the roof. Another constraint is the structural capacity of the accommodating building, which as indicated by Jenkins (2018) and Sanyé-Mengual (2015), can become the fundamental limitation for the scale of UF operation. For instance, the load-bearing capacity analysis of the obsolete building chosen for the Biospheric Project revealed that the implementation area for the PFSL and the RTG was significantly reduced by the structural capacity of the building and the requirement to reinforce the construction (Jenkins, 2018). Thus, the structural capacity assessment of the accommodating building is crucial for making informed decisions regarding the spatial potential of the building for CEA.

4.5.3. Environmental exploration of case studies

Table 12: Summary of the environmental analysis of urban farms selected for the case study research

UF	WATER SAVING AND RECYCLING	ENERGY SAVING	ALTERNATIVE ENERGY TECHNOLOGY OPTIONS
Grow Bristol	Closed-loop plant cultivation system	Optimal management of indoor microclimate	-
Biospheric Project	Closed-loop plant cultivation system	LED lighting; Optimal management of indoor microclimate	-
BIGH Ferme Abattoir	Closed-loop plant cultivation system; Rainwater harvesting	Semi-closed greenhouse; Heat exchange; Reuse of CO_2 and O_2; Energy-efficient pumps and boilers; LED lighting; Optimal management of indoor microclimate	BIPV; Industrial waste heat exchange

The exploration of resource and energy-efficient technologies and alternative energy technology options in urban farms selected for the case study research (Table 12) indicated that environmental benefits derived through the installation of such technologies are well understood. In all analysed cases, the optimal management of the indoor microclimate and closed-loop cultivation systems play a crucial role in resource-saving. However, the scale of the CEA operation bolsters the requirement for sustainable technologies and environmental synergies between uses, due to the possibility to reduce resource use, which results in lower economic costs.

4.6. Summary of Chapter 4

The chapter commenced with the literature review on the planning opportunities and limitations perceived by stakeholders regarding up-cycling buildings for CEA, which led to the identification of social, economic, environmental, technical, aesthetic, as well as policy and partnership benefits and constraints (Table 7). Then, linking the defined opportunities as the key drivers and motivations for the proposed adaptive reuse with the objectives of the urban area defined in planning documents was recognised as the strategy for improving the acceptance of such adaptive reuse, as well as enhancing the project on the local level. The architectural topic areas, including the architectural form for CEA, the orientation of an architectural form for CEA, materials to enclose a space for CEA, and the structure of the building adaptively reused for CEA were investigated in the following section of the literature review. The findings include recommendations for making the architectural decisions crucial for the viability of the CEA operation (Table 8). The last section of the literature review revealed resource and energy-efficient technologies, alternative energy technology options and environmental synergies with other uses as being prominent for the ecological viability of the adaptive reuse of urban structures for CEA (Table 9).

The case study analysis conducted through the framework which arose from the literature review indicated the viability of the planning, architectural and environmental secondary findings for RTGs, PFSLs and PFALs. As no examples of an operating FF were identified, the theoretical knowledge on this CEA type cannot be validated. The next chapter narrows down the investigation to modern movement car parking structures. This is done by analysing semi-structured interviews with experts and generating primary data relevant for further research.

Chapter 5: Interviews with practitioners

5.1. Introduction to Chapter 5

Chapter 4 reviewed the existing literature on the planning, architectural and environmental design aspects, which from the architect's perspective contribute to the adaptive reuse of inner-city buildings for viable CEA operations. In Chapter 5, the research focus narrows to a specific type of modern movement architecture: multi-storey car parking structures located in inner-city areas. The primary investigation, conducted through 15 semi-structured interviews, aims to identify planning, architectural and environmental criteria for retrofitting these urban structures for CEA at the initial stage of the design scenario development, and to investigate limitations and opportunities which should be analysed in order to address the criteria from the perspective of professionals. Finally, the implications of the findings for the development of the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures are explored.

5.2. Interview design

The literature review revealed three thematic categories of relevance from the architect's standpoint for up-cycling buildings for CEA: planning, architectural and environmental. These thematic categories were the focus of the interview design. The questionnaire is shown in Appendix C.

Planning

The main aim of this category of questions is to explore stakeholders' knowledge on the strategy which should be adopted by the architect to develop key drivers and motivations which can be used when engaging with a local authority to obtain planning permission for the change of use of an inner-city modern movement car parking structure for CEA. To get a better understanding of the experts' perception of the proposed up-cycling, the familiarity and acceptability of the concept are discussed. Then, the opportunities and limitations for the retrofit are explored in the planning context of the three inner-city areas selected for the explanatory case study research. The primary data obtained from the interviews allows the formulation of the planning criteria which should be met to repurpose inner-city modern movement garages for viable CEA operations.

Architecture

The main aim of this category of questions is the architectural analysis of modern movement car parking structures, which leads to the determination of the initial architectural strategy for the design of viable CEA operations. While the literature review revealed that it is often contentious whether the obsolete structure should be adaptively reused, or demolished and replaced by a new build (Berg & Fuglseth, 2018; Bull, Gupta, Mumovic, & Kimpian, 2014; Gaspar & Santos, 2015; Hasik et al., 2019; Schwartz, Raslan, & Mumovic, 2018; Vandenbroucke, Galle, De Temmerman, Debacker, & Paduart, 2015; Vilches, Garcia-Martinez, & Sanchez-Montañes, 2017), the interviews commence with the identification of whether the architecture of multi-storey garages is seen as a valuable resource in inner-cities. Then, the architectural opportunities and limitations for the proposed up-cycling are discussed to identify specific modifications required for the viability of the initial design scenario development. The primary data obtained allow the formulation of the architectural criteria which should be met to repurpose inner-city modern movement garages for viable CEA operations.

Environment

When implementing CEA within the urban fabric, concerns arise regarding its increased reliance on urban resources (Kozai, 2016; Kozai et al., 2015; Kozai, Ohyama, & Chun, 2006; Ting et al., 2016). Therefore, the main aim of this category of questions is to explore the experts' perception of up-cycling modern movement garages, to conceptualise the future position of these buildings within the urban sustainability concept. This is done by exploring environmental opportunities and limitations for the proposed adaptive reuse. Then the discussion narrows to the specific technologies which may be implemented when repurposing car parking structures for CEA to minimise the use of urban resources and to produce energy. The primary data obtained allow the formulation of the environmental criteria which should be met to repurpose inner-city modern movement garages for viable CEA operations.

5.3. Representation of interview participants

The participants were strategically chosen on the basis that they were:

- Sustainability officers and urban planners (public administration officers) in Portsmouth, Bristol and Brighton & Hove;
- Experts in the sector of architecture and urban regeneration;
- Experts in the sector of building-based CEA;
- Researchers in the field of architecture and UF.

Participants were selected with the aim of understanding their points of views, experiences and visions concerning three main thematic categories related to the adaptive reuse of inner-city modern movement car parking structures for CEA: planning, architectural and environmental. The professional experience of the participants and their significant position within organisations ensured that their point of views and visions were informed, and therefore their opinions can be considered sufficiently reliable. Information on the job position, area of expertise, number of participants and the contribution to the thematic categories is provided in Table 13.

Table 13: Interview participants: experts' group, area of expertise, number of participants and contribution to the thematic categories

Experts	Area of expertise	No.	Contribution		
			P	A	E
Architects	Design of urban farm in/on existing buildings, Design of inner-city car-parking structure, Adaptive reuse of buildings/sites, Integration of sustainable technologies in design, Sustainable development, Urban planning documents	3	X	X	X
Urban farmers	CEA, Building-based farming, Adaptive reuse of buildings/sites for CEA, Economic viability of CEA	3	X	X	X
Researchers	Building-based farming, Technologically advanced farming techniques, Adaptive reuse of buildings/sites for CEA, Integration of sustainable technologies in CEA, Synergies between CEA and existing building	3	X	X	X
Public administration officers	Sustainable development, Urban planning, Adaptive reuse of buildings/sites, Urban planning strategies, Development of green strategies, Knowledge of planning documents	3	X		X
Consultants working with cities on planning resilient food systems	Strategic policy for developing UF, Engaging with the local authority for UF, Community engagement in UF, Food partnership, Collaborative marketing	3	X		

5.4. Preliminary analysis of the interviews

5.4.1. Planning considerations

Responses to the first question in this thematic category revealed that the adaptive reuse of inner-city modern movement car parking structures for CEA is not a common practice, but is potentially acceptable. However, the opinions expressed were divided across three groups of attitudes. First, with three out of 15 interviewees (20 percent) expressing this view, the adaptive reuse of modern movement garages for CEA is not familiar, but is an acceptable and emerging practice. One architect interviewed had practical experience in up-cycling a multi-storey car park for CEA. One researcher reported his theoretical support for retrofitting some areas of a multi-storey garage attached to a shopping centre with hydroponics. One architect was a member of a team that designed a car parking structure aimed at maximising the possibility for retrofitting it for another use, taking CEA into consideration. While several architectural limitations can be identified for up-cycling these structures designed for cars, CEA has different spatial requirements and can be developed within or upon multi-storey garages. Two respondents highlighted this fact as being beneficial from a circular economy perspective. The second attitude identified, with nine out of 15 interviewees (60 percent) expressing this view, shows that the adaptive reuse of inner-city multi-storey garages is not a familiar concept, but such an up-cycling would substantially increase the spatial potential for implementing UA and therefore, is highly acceptable. Five interviewees argued that some buildings need to be designated for CEA in the future, as this would improve food security in cities and reduce the negative environmental impact of the global food supply. A recurrent theme within this category was the opportunity to develop large-scale CEA within and upon car parking structures as an economically viable business. Two interviewees highlighted that increasing the urban productive area by retrofitting multi-storey garages with CEA may allow for developing a UA brand that connects UF enterprises. The third group of attitudes, represented by three out of 15 interviewees (20 percent), indicated that the adaptive reuse of car parking structures for CEA is not a familiar concept, and it would not be accepted in the future. A common view among this group was that inner-city multi-storey garages will be needed in the future, although they are currently underutilised. When discussing the case of London Road Car Park in Brighton & Hove, one participant commented:

Car parks are a significant source of income for their owners (in this case, the city council). It therefore seems likely that the council would seek to maximise revenue from a defunct car park, either in terms of its capital value (e.g. selling to a developer) or as a long-term resource (e.g. renovating it as retail/storage/office space for rent).

This response indicated the prioritisation of more cost-effective uses than CEA when considering up-cycling an inner-city garage, which may lead to the decision to demolish the structure replace it with a new development, resulting in higher financial profits.

When asked whether CEA should be implemented as a permanent or temporary use in retrofitted inner-city multi-storey garages, 60 percent of participants (9 out of 15) indicated the temporary basis as the correct strategy. A common view among respondents was that due to urban land values and continuously changing market demand, a meanwhile lease would be the only possible option offered by the owner of the garage. Talking about this issue, an interviewee said:

The value of the land is growing so fast that it may be much more profitable for the city council to sell it, for instance for a housing developer. The value is the biggest problem that we face right now and for that reason, we try to protect urban space for food. UA projects, including CEA, should be able to move.

This view was echoed by another respondent, who said that the location of CEA businesses is often temporary due to competing demands for space in cities. The development of a detailed business model allows for adapting the tenure to a UA project. After that period, the crucial issue is to find another location which would fit the existing CEA installation, and continue the business. Some interviewees argued that first, some areas of a multi-storey car parking structure should be reused for CEA as a temporary pilot project, which would educate stakeholders and the local community about this technical food system and its aims within the urban environment. Then the decision could be made on extending the project duration, moving it to a different location, or terminating it. Such an approach offers greater flexibility for decision makers, who consider the proposed up-cycling as an innovation whose social, environmental and economic effects are difficult to assess.

For 40 percent of participants, repurposing multi-storey garages with CEA should be permanent. The main reason for this approach are the high initial costs associated with such up-cycling, as well as the purchasing and installation of the technology required for food growing. From the perspective of farmers who run UA businesses, the permanent location of CEA in a multi-storey car parking structure is a more economically viable solution. The diversification of a CEA project is considered essential for making the proposed adaptive reuse permanent, owing to the social, economic and environmental benefits which would arise as a result. For two participants, the adaptive reuse of buildings, including multi-storey garages, for CEA is the only possible solution for feeding the world's growing population and for this reason, within forward-thinking cities, it must be permanent.

When the participants were asked about planning opportunities for the adaptive reuse of inner-city car parking structures for CEA, all of them listed approaches which should be considered in the initial stage of a project to provide supportive arguments for the proposed development. Analysing planning documents for the district where the multi-storey garage is located was highlighted as the crucial opportunity for recognising and implementing actions contributing to the strategic objectives of the specific inner-city area. Conceptualising how to meet these objectives at the initial stage of the design proposal development was seen as the foremost opportunity for obtaining planning permission for the change of use of the car parking structure by 12 out of 15 interviewees (80 percent). This type of strategy was broadly explained in discussions with consultants working with cities on planning resilient food systems (20 percent). One respondent reported:

You need to analyse existing strategies of the local authority (…) or the health and well-being documents. Such investigation allows identifying crucial strategy, which supports your CEA proposal (…). Exploring what the overlap is for what you are trying to achieve and addressing that in the adaptive reuse project would be the core opportunity for developing the proposed up-cycling.

Specific social, aesthetic or economic improvements which could be delivered by repurposing inner-city modern movement garages for CEA in the areas selected for the case study research were discussed by all 15 respondents (100 percent). 14 out of 15 respondents (93.4 percent) highlighted community engagement as a crucial opportunity for up-cycling car parks for CEA. Education was indicated as the first option to be considered. Nine interviewees reported providing training in food growing, healthy eating and cooking as the primary activity to be developed alongside the CEA project. Allowing the local community to actively participate in crop cultivation was reported as being highly expected by the local authority by eight respondents (53.4 percent). Involving children from the neighbourhood and local schools in UF was seen as an opportunity by five interviewees (33.4 percent). Job creation for the local community within the proposed UA enterprise was considered beneficial by five participants (33.4 percent). Three out of 15 participants (20 percent) highlighted providing space for social events within the up-cycled car parking structure as an opportunity to derive further social value in inner-city areas.

Nine out of 15 respondents (60 percent) reported the interrelatedness of social improvements with the health benefits which may be delivered by the up-cycling discussed. Improved access to nutritious food as well as the organisation of educational programmes focused on healthy eating and cooking was highlighted by 5 participants (33.4 percent) as a potential overlap with urban strategies aimed at reducing food poverty, food and health inequalities, malnutrition and obesity. Linking the proposed CEA project with organisations (e.g. Sustain) and their campaigns promoting healthy eating (e.g. Veg Cities) was reported as a further contribution to the health agenda in the UK (26.7 percent).

Eight interviewees (53.4 percent) highlighted the opportunity to create space for innovations and research by retrofitting inner-city multi-storey garages for CEA. Specific research areas to explore within the proposed development would be focused on resource use efficiency (53.4 percent), nature-based solutions in urban areas (26.7 percent), innovative food production techniques (20 percent), circular economy (20 percent) and the food-water-energy nexus (13.4 percent). These research areas were seen as contributing to sustainable urban development and resilience (60 percent of participants).

Nine interviewees (60 percent) paid particular attention to the financial aspects of up-cycling inner-city multi-storey garages for CEA. Proposing adaptive reuse as a long-term economically viable business was seen as a crucial opportunity for accepting CEA as an alternative use for a car parking structure. Four beneficial strategies emerged during discussions. First, extending revenue opportunities (60 percent of responders) primarily through offering educational facilities, organising site tours, testing UF innovations, developing food processing facilities, on-site food consumption and a shop for retailing products grown on the farm. Second, employing circular economy principles (46.7 percent) by integrating local resources, employing local labour, organising local distribution and building a long-term relationship with other urban and rural farmers from the region. Third, engaging in collaborative marketing (33.4 percent) to become a member of a network of urban farmers, who sell products under a single brand, and exchange information, marketing strategies and technology. Fourth, developing local distribution channels (33.4 percent), including transport direct to consumer, and collaborations along the supply chain. The respondents highlighted that the implementation of the strategy for reducing the costs of the CEA project depends on the urban and economic context, and needs to be targeted at the specific multi-storey garage selected for up-cycling.

Seven out of 15 interviewees (46.7 percent) indicated environmental opportunities arising from repurposing inner-city car parking structures for CEA. The specific benefits may be achieved through the implementation of UA as a way to reduce the adverse impact of the global food supply, including minimised food miles and reduced pressure on agricultural land. Further opportunities were identified if passive technologies are implemented, if or synergies between UF and neighbouring building are developed.

Six out of 15 interviewees (40 percent) indicated the improved aesthetics of a multi-storey garage as a potential benefit from the local authority’s perspective, derived from the proposed adaptive reuse for CEA. All six interviewees reported the need to modernise the car parking structures selected for the case study research. Three participants (20 percent) argued that greening these buildings, especially the external façades and unused rooftops, would benefit the aesthetics of the ambient urban environment.

When discussing planning limitations for up-cycling inner-city modern movement car parks for CEA, 11 out of 15 interviewees (73.4 percent) indicated obtaining planning permission for the change of use for UA as the primary planning challenge. Each respondent believed that this constraint arises from a lack of knowledge around the proposition of up-cycling for UA purposes, which makes assessing the social, environmental and economic performance of the proposed adaptive reuse difficult. Nine interviewees (60 percent) associated a lack of knowledge in building-based CEA with numerous uncertainties, which would make the development of this innovative use much more complicated due to regulatory gaps regarding this use in the legal framework. Lack of supportive policies was highlighted as a substantial constraint. None of the respondents identified any guidelines on the implementation of building-based CEA in the urban planning documents of Portsmouth, Bristol or Brighton & Hove. CEA was not indicated as a possible site allocation designated in land zoning.

A lack of knowledge on building-based CEA was associated with potential misunderstandings regarding the development of the food production system in the inner-city, for instance, noise, air and light pollution as well as transportation problems, which may lead to the rejection of the up-cycling proposal. When talking about this issue, the public administration officer said:

(…) food growing is a part of green infrastructure, but I think having less awareness, less experience and knowledge expertise in UA creates a barrier to progressing and implementing this type of green infrastructure projects across the city.

Classifying building-based CEA as a form of green infrastructure caused additional concerns regarding implementation and maintenance, and the financial inputs required for the proposed up-cycling project. Five out of 15 respondents (33.4 percent) explained that high initial and operating costs are associated with the implementation of hydroponic technology and alternative technology options, enclosing the multi-storey garage for CEA, controlling the internal environmental parameters, and the high demand for resources, especially energy.

Six participants (40 percent) indicated that repurposing the selected multi-storey garages for CEA would be questioned due to their location in inner-city areas. The competing demands for space and high land value in central urban districts were reported as the critical reasons why UA (e.g. allotments) is often moved to peri-urban areas or is reduced. Two participants echoed the issue of a lack of supportive policies for UA, which do not guarantee any protection for agricultural land, and allows the allocation of investments with higher social or economic priority on farming areas, especially within central urban districts. For CEA businesses, local authorities prefer meanwhile leases as they offer higher flexibility in building management. As a result, CEA can be easily moved when a more cost-effective investment is identified. Six out of 15 participants (40 percent) argued that there is lower acceptance of CEA than traditional in-soil UF among decision makers and urban residents. This is because of several social benefits associated with UA and high demand for allotments.

In response to question 4 from the planning category, all of those interviewed commented that the adaptive reuse of inner-city car parking structures for CEA would receive more support from a local authority when developed with additional facilities. The selection of particular facilities would arise from the analysis of site-specific requirements indicated in local planning documents. Five out of 15 respondents (33.4 percent) highlighted that the exploration of limitations and opportunities for the areas selected for the case study research would bring crucial insights into the potential improvements to be brought together with the up-cycling of a multi-storey garage for CEA. The implementation of a mixed-use building with social uses was reported as the most significant contribution to the urban areas analysed by 14 out of 15 respondents (93.4 percent). Eight out of 15 interviewees (53.4 percent) explained that the proposed development might be more economically viable when supported by product processing, packing, distribution, preparation and retail facilities (e.g. organic shop, marketplace). Such uses were strongly advocated by urban farmers, researchers, and architects with practical experience in building-based CEA. At the same time, public administration officers raised concerns regarding the environmental issues caused mainly by food processing and transport in inner-city areas. One expert with experience in the architectural design of building-based CEA, who was the CEO of a CEA business, recommended developing a product self-collection space, which would minimise the food delivery issue. Repurposing a modern movement garage for CEA as a food innovation and research centre was considered beneficial by 40 percent of respondents. Forty percent of interviewees discussed the opportunity to up-cycle multi-storey garages for a creative and flexible space for start-up organisations focused on sustainable food production, transportation and consumption. All respondents highlighted that the selection of additional facilities for the proposed adaptive reuse is context-specific and cannot be transferred between car parking structures located in various urban environments. The planning opportunities and limitations that arose from the preliminary analysis of the interviews, and the percentage of interviewees indicating the various opportunities and limitations is presented in Table 14.

Table 14: Planning opportunities and limitations that arose from the preliminary analysis of the interviews, percentage of interviewees indicating these opportunities and limitations

	OPPORTUNITIES	%		LIMITATIONS	%
1	Improved social cohesion: - education, - job development, - community food growing, - space for social events	80	1	Approval of the change of use of a car parking structure for CEA: - lack of supportive policy, - lack of guidelines on the implementation of building-based CEA in urban planning documents, - UA not designated as a site allocation in land zoning	73.4

2	Improved health of urban residents: - improved access to nutritious food, - education on a healthy diet	93.4	2	Lack of knowledge on building-based CEA: - difficulties in assessing the social, environmental and economic performance of proposed adaptive reuse, - misunderstandings about transportation of the agricultural product, - assumptions about potential issues (e.g. noise, air and light pollution)	60
3	Space for innovations and research: - resource use efficiency, - nature-based solutions in urban areas, - innovative food production techniques, - circular economy, - food-water-energy nexus	60	3	Lack of space protection for UA: - meanwhile leases for CEA, - prioritising more cost-effective investments, - prioritising investments with higher social value	40
4	Long-term economic viability of the CEA project: - adapted circular economy principles, - extended revenue opportunities, - involvement in collaborative marketing, - development of local distribution channels	53.4	4	Lower acceptance of CEA than community food growing by: - decision makers, - urban residents	40
5	Reduced adverse environmental impact of the current food supply system and urban development: - reduced food miles, - lower pressure on the agricultural land, - passive technologies, - synergies between CEA operations and other uses	60	5	High initial and operating costs of CEA: - hydroponic technology, - alternative energy technology options, - enclosing the space for CEA, -control of the internal environmental parameters, - high demand for resources	33.4
6	Improved aesthetics of a car parking structure: - greening the building, - modernisation	40			

5.4.2. Architectural considerations

In response to the question: 'Do you consider multi-storey car parking structures from the modern movement era as having architectural value in inner-cities?' 11 out of 15 interviewees (73.4 percent) confirmed the high architectural value of multi-storey garages and their potential role for implementing CEA in central urban districts. This value was not associated with the aesthetics of the concrete garage, but with the existing space as a resource, which may be repurposed for other functions due to the flexibility and modularity of this type of architecture. As one interviewee said:

There are obviously more buildings to be up-cycled than new buildings to be built in the world. If you take particularly multi-storey garages that have a large area (…), there is a lot to do.

Another participant indicated the architecture of the existing multi-storey garages as a valuable resource, which may be converted to an alternative use to maximise revenue from these increasingly redundant buildings:

A lot of them are empty and they (National Car Park) *do not know what to do with them. A lot of these properties are also in shopping centres. And retail development has had rock bottom at the moment. There are many empty properties where first of all, there are car restraint policies, people all not encouraged to drive in any longer and then they cannot sell it for development. Therefore, their owners are looking for a use for them.*

The architectural value of modern movement garages was further associated with circular economy principles (three participants), where refurbishing existing building stock was seen as a crucial strategy for developing CEA. From this standpoint, the architectural value of multi-storey car parks was linked to environmental and economic benefits, due to the preservation of the embodied energy of these structures and reduced costs compared to demolition and new build.

Four respondents (26.7 percent) questioned the architectural value of modern movement car parking structures, and revealed that it is difficult for them to conceptualise the up-cycling of these garages for CEA. These views surfaced mainly concerning the current urban planning context in UK cities, where the high value of inner-city land and the prioritisation of more cost-effective investments were seen as crucial arguments for the demolition of concrete garages and new construction. There were a range of responses to this question, strongly dependent on the level of expertise on up-cycling of buildings and CEA. Respondents with professional and theoretical knowledge on adaptive reuse and CEA indicated a high architectural value for multi-storey garages, while public administration officers and consultants working with cities on planning resilient food systems negated this value. For example, when talking about London Road Car Park in Brighton & Hove, one interviewee said:

(…) it is a sort of dry, a sort of brutalist kind of building so the question is how you could soften it (…). From the urban planning perspective, there is a scope for demolish it and then build something completely new to add architectural value to what is there (…).

The first architectural opportunity identified for the adaptive reuse of modern movement garages for CEA was the flexibility of the existing architectural form, which offers multiple options for implementing CEA units. The respondents considered developing CEA installations within the car parking structure (100 percent) as a PFSL or a PFAL, or upon it as an RTG (100 percent) and on elevations as FFs (13.4 percent). Eight out of 15 informants (53.4 percent) identified the modularity of layouts as being beneficial for the proposed development. Repeatable plans and the identical dimensions of parking bays were associated with the possibility to design modular hydroponic units and alternative energy technologies which would be easy to transport to another garage.

The accessibility of multi-storey car parking structures through existing ramps, staircases and lifts was identified as an opportunity by four out of 15 respondents (26.7 percent). These architectural elements would enable the efficient circulation of vehicles, people and goods. However, all four respondents highlighted that the circulation routes would need to be adjusted to the requirements of the new use. Two respondents (13.4 percent) suggested that multi-storey garages can easily be closed to prevent break-ins, unauthorised access, theft and damage. This aspect was seen as a significant opportunity for securing costly hydroponic installations and the crops produced.

When discussing architectural limitations for the adaptive reuse of inner-city car parking structures for CEA, 8 out of 15 interviewees (53.4 percent) indicated the structural conditions of modern movement garages as the main challenge. This group of respondents highlighted that understanding the structural limitations of multi-storey garages would be crucial for making informed design decisions regarding the location of facilities and the CEA installation. For this category of constraints, the load-bearing capacity, as well as deflections and cracking, were highlighted as the critical issues.

Enclosing the car parking structure for creating a controlled environment was identified as a further architectural limitation by 11 interviewees (73.3 percent). 7 out of 15 respondents (46.7 percent) expressed that this issue includes the decision on technology for enclosing the space for CEA, while 5 participants (33.4 percent) reported the selection of infrastructure for controlling different parameters of the environment inside the building for UA. These limitations were associated with high initial financial inputs for the proposed up-cycling and the environmental challenges related to the increased use of urban resources.

Eight out of 15 interviewees (53.4 percent) considered adapting structural elements of multi-storey garages for this alternative use as a limitation. The distances between concrete slabs were reported as being too low for repurposing these building for social uses, for instance, housing or a hotel. One respondent proposed to partially take out concrete slabs in some areas of a multi-storey structure to obtain an adequate floor-to-floor height. 13.4 percent of participants identified the existing grid of columns as a constraint, which could require building a modular hydroponic installation fit to the specific garage. Interestingly, 26.7 percent of respondents perceived the existing grid of columns as an opportunity in terms of flexibility of space and modularity that would allow for multiplying hydroponic installations within and upon one car parking structure.

One interviewee with practical and research experience in building-based CEA highlighted that the structural elements of a multi-storey garage might limit natural light from accessing the interior. This issue could become a critical limitation for the viability of the proposed development, owing to the reduced productivity of hydroponic installations under artificial lighting (Jenkins, 2018) and the increased use of energy (Kozai, 2016). Talking about this issue, an interviewee said:

When growing in buildings and not upon them, you are restricted in the use of natural light, which mean you become reliant on artificial lighting, which is a less efficient way of growing crops. (…) indoor vertical systems that are artificially lit are five times less efficient than growing food in a traditionally lit greenhouse. (…) another thing is the energy concern, so how much energy is going to the food production in a car parking structure and can this energy be delivered by any sustainable technologies preferably installed within the car park itself to utilise it for growing food.

Addressing limited natural light access through appropriate architectural decisions, especially regarding the location of hydroponic units, was considered crucial for the economic and environmental viability of the proposed adaptive reuse for CEA.

Another limitation identified was the requirement to adapt circulation to new uses. Twenty percent of interviewees highlighted that difficulties might arise regarding the architectural modifications of existing ramps, staircases and lifts. Three respondents (20 percent) linked this limitation to fire safety, which must be addressed in the design stage of any proposed development.

When discussing the architectural modifications which should be investigated for the initial up-cycling scenario for CEA to address the opportunities and limitations identified, respondents provided several recommendations for the alteration of the structure, circulation, elevations and the material used. First, the structural assessment of the multi-storey garage must be conducted by a qualified structural engineer. The importance of the load-bearing capacity and examination of the technical conditions on the initial stage of the design process was highlighted by seven out of 15 interviewees (46.7 percent). Further structural modifications of multi-storey garages advocated by the interviewees included the adjustment of a too low floor-to-floor height, for instance by partially taking out concrete slabs in some areas of a building.

Second, to enclose the structure for CEA, five participants (33.4 percent) advocated the use of permeable cladding materials, which maximise sunlight transmissivity which is beneficial for crop cultivation and the energy efficiency of the system developed. The recommended materials were glass and ETFE foil. The responses in this category included suggestions for the location of hydroponic growing installations within and upon the multi-storey garage. Although the majority of interviewees agreed that crop cultivation in a controlled environment could be carried out solely under artificial lighting, some experts argued that hydroponic units should be placed in areas lit by natural light, due to increased productivity and the reduced energy requirements for artificial lighting. Owing to these reasons, ten respondents (66.7 percent) advocated the placement of a greenhouse on the rooftop level of a car parking structure. Interestingly, two respondents proposed the location of shipping containers in and on the building as a module for a CEA installation, which minimises the need for installing external cladding and allows the creation of an artificially lit controlled environment in individual areas of a multi-storey garage.

Third, the existing circulation, including ramps, staircases and lifts, was considered an opportunity for the adaptive reuse of modern movement garages for CEA. However, four experts (26.7 percent) highlighted the need to adjust these architectural elements for the new use. For CEA, crucial issues include efficient transport of the product in and out of the garage, where the location of ramps and lifts is a primary concern.

Finally, four respondents (26.7 percent) proposed architectural modifications advantageous for the aesthetics of the existing building and its attractiveness in the inner-city area. The alterations listed focused mainly on the implementation of green façades and rooftops. Further proposed modifications included appealing frontages at the ground floor level and the development of a volume as an extension of an existing garage for locating a CEA installation. The architectural opportunities and limitations which arose from the preliminary analysis of the interviews, and the percentage of interviewees indicating these opportunities and limitations is presented in Table 15.

Table 15: Architectural opportunities and limitations that arose from the preliminary analysis of the interviews, percentage of interviewees indicating the opportunities and limitations

	OPPORTUNITIES	%		LIMITATIONS	%
1	Flexibility of layouts for the functional arrangement of space for CEA including: - internal space (PFAL & PFSL), - external space (RTG & FF)	100	1	Structural conditions of the concrete building: - load-bearing capacity, - deflections and crackings	53.4

2	Modularity of layouts for the possibility to design modular hydroponic units and alternative energy installations that are easy to transport to another car parking structure: - repeatable plans, - repeatable parking bay dimensions: 2.4m x 4.8 m	53.4	2	Creation of a controlled environment in the car parking structure: - selection of technology to enclose the structure, - selection of infrastructure, which allows controlling different parameters of the internal environment	73.3
3	Accessibility for people and vehicles through existing: - ramps, - staircases, - lifts	26.7	3	Adaptation of the structural elements of a multi-storey garage for CEA installations: - floor-to-floor height, - distances between columns	53.4
4	Security: the structure can be easily closed to prevent breaking-in unauthorised access, theft and damage	13.4	4	Adaptation of circulation for CEA: - ramps, - staircases, - lifts	20
5	Improved aesthetics of the multi-storey garage: - greening the building, - modernisation	40	5	Fire safety	20

5.4.3. Environmental considerations

When the participants were asked if they consider the adaptive reuse of inner-city modern movement car parking structures as being of value in terms of environmental sustainability, the majority commented that extending the life cycle of an existing building contributes significantly to the environmental sustainability of urban areas. However, only five interviewees (33.4 percent) presented a more in-depth understanding of this topic. This group of experts discussed the environmental benefits of the proposed up-cycling from the building's life cycle perspective. The energy embodied in the existing building was seen as the fundamental value retained when the building is adaptively reused. One individual stated:

The idea of renovating and reusing instead of demolishing is highly relevant because demolishing, especially reinforced concrete and redeveloping a new building is a significant issue that produces vast amounts of CO_2.

Retrofitting inner-city modern movement garages with UA was recognised as a more environmentally viable way of implementing building-based UF, compared to developing a new-build architecture for urban food growing:

The adaptive reuse of multi-storey garages definitely represents an environmental value because I would expect that the embodied energy of a new building was so high that you would never be able to justify it by using for the local food production. (...) The embodied energy of all the concrete, *steel and the demolition of the existing building and the economic viability of that is the main reason why it has not been done yet. (…) we should definitely grow food within and upon existing buildings. If they are empty, they are right to use in any way people want to use them, so urban food production is an excellent way of using existing structures. It puts food production exactly where it is needed, which is inside the city.*

Architects and researchers explained the potential environmental benefits arising from retrofitting multi-storey garages. Other respondents (20 percent), although acknowledging the environmental values of the proposed up-cycling, suggested that in many cases new economic opportunities from the demolition of the modern movement structure, and new build targeted at specific uses in high market demand could exceed environmental aspects. One interviewee suggested that there are uses with higher priority in the inner-city, for instance housing, and it is difficult to conceptualise how these would be implemented within multi-storey garages. Thus, demolition, although having adverse environmental impacts, would deliver more social and ecological values for the city.

When asked about the key environmental opportunities for the adaptive reuse of inner-city modern movement car parking structures for CEA, 12 out of 15 participants (80 percent) indicated the importance of implementing resource and energy-efficient technologies and alternative energy technology options for reducing the reliance of UF on urban resources. In all interviews, in response to this question, participants suggested specific methods and technologies for saving resources and producing energy. Thus, the answers to question 1 evolved in the considerations for question 4, specifically the analysis of technologies which should be implemented when repurposing inner-city garages to minimise the use of urban resources and produce energy by alternative technology options. Eight out of 15 participants (53.4 percent) highlighted the use of energy-efficient lighting, specifically LED lighting, as a crucial opportunity for decreasing the energy demand of CEA installations. The lighting system may be more energy efficient when installing a lighting control system. Regenerating alternative freshwater sources, especially greywater and water harvesting, were discussed by seven interviewees (46.7 percent). Another opportunity for environmental savings in the CEA practice that was considered by six experts (40 percent) was the optimal management of the indoor microclimate of the UF operation. Five respondents (33.4 percent) advocated the use of a closed-loop plant cultivation system. The implementation of alternative energy technology options, including solar power systems (e.g. PV panels), wind power systems (e.g. Wind Assured system), ground sourced heat pumps and biomass was indicated by 12 interviewees (80 percent).

A significant opportunity for reducing the environmental burdens of the proposed adaptive reuse for CEA was associated with the development of technical synergies between CEA and other uses located within the accommodating structure or neighbouring buildings. Six out of 15 participants (40 percent) considered the possibility to exchange energy, water, organic waste or waste heat as a result of such synergies.

Six participants (40 percent) reported that a significant environmental limitation is that innovative technology may not be compatible with the existing infrastructure in a modern movement car-parking structure. One interviewee commented:

There are many potential technologies, but the problem is that the infrastructure may not fit together. Many developers of farming projects have told us that they had many good ideas about how they could improve the sustainability of their projects, but they could not implement them because that would be too expensive or just impossible.

As this statement indicates, this constraint was associated with the high initial costs of implementing resource and energy-efficient technologies, alternative energy technology options and developing technical synergies between various facilities within the adaptively reused building (40 percent). A lack of technologies required for developing environmental synergies between CEA installations and additional uses was recognised as a further barrier for the adaptive reuse of multi-storey garages. Two participants (13.4 percent) with a research background highlighted that this limitation requires technical innovations and multidisciplinary research. The planning opportunities and limitations which arose from the preliminary analysis of the interviews and the percentage of interviewees indicating these opportunities and limitations is presented in Table 16.

Table 16: Environmental opportunities and limitations that arose from the preliminary analysis of the interviews, percentage of interviewees indicating the opportunities and limitations

	OPPORTUNITIES	%		LIMITATIONS	%
1	Resource-efficient technologies and alternative energy technology options: - optimal management of indoor microclimate, - energy-efficient lighting (LED lighting), - lighting control system, - regenerating alternative freshwater sources, - rainwater harvesting, - closed-loop plant cultivation system, - solar power systems (e.g. PV panels), - wind power systems (e.g. Wind Assured system),	80	1	Innovative infrastructure may not be compatible with existing infrastructure in a multi-storey car parking structure	40

	- ground sourced heat pump, - biomass				
2	Synergies between CEA and other uses: - exchange of energy, - exchange of water, - exchange of organic waste, - exchange of waste heat	40	2	High initial costs of implementing: - resource and energy-efficient technologies, - alternative energy technology options, - technical synergies	40
			3	Lack of innovative technologies required for developing synergies between CEA installations and additional uses	53.4

5.5. Interpretation of the results of the interviews

5.5.1. Planning category of questions

The adaptive reuse of inner-city car parking structures for CEA is not a familiar concept. However, there is an agreement between experts that building-integrated UA is emerging in urban areas worldwide as a response to the social, economic and environmental impacts of the global food system. In this context, multi-storey garages are a valuable resource that when adaptively reused can provide a space within a dense urban environment for CEA. This attitude is based on two aspects of UA highlighted in the literature. First, traditional in-soil farming activities are often challenged by competing demands for space in inner-city areas (Lovell, 2010; Specht et al., 2013). Multi-storey garages are seen as an opportunity to increase and enhance urban food production. Second, the size of UF installations plays a crucial role in the economic viability of UA as a business (Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). A large-scale CEA practice is associated with greater potential to succeed as an economically viable business. Thus, repurposing car parking structures for CEA is seen as an opportunity for the enhancement of UA on the commercial scale. However, the experts revealed that the proposed retrofit is perceived as an innovation that is challenging to conceptualise in urban settings. This attitude was presented by public administration officers and urban planners, who play a crucial role in the administration process leading to the change of use of a given multi-storey garage.

The majority of respondents argued that the up-cycling of inner-city multi-storey garages for CEA would be possible on a temporary basis, specifically as a meanwhile lease before a more profitable investment is proposed. The key argument for such an approach is the revenue from the existing structure, and the belief that demolition and new build would increase financial profits (e.g. housing). These results reaffirm the findings from Sanyé-Mengual et al. (2016) and Specht et al. (2015) that building-based CEA is seen as an innovation not targeted at economic benefits. A similar approach to the duration of the UF project and type of lease is indicated by Davis (2018), Thomaier et al. (2014) and Wachter & Scruggs (2010) as a preferred option by decision makers. As a result of the location uncertainty, many interviewees recommended installing modular mobile farming units, which could be moved to other compatible buildings. Such an attitude may lead to innovative planning decisions (Thomaier et al., 2014) regarding the specific location of such units and the plan of the implementation area in response to the limited duration of the tenancy.

The crucial criterion arising from the results of the analysis of responses to the planning category of questions is that the local authority must allow the up-cycling of the inner-city modern movement car parking structure and accept CEA as a future use. The experts proposed exploring current planning documents and identifying how up-cycling multi-storey garages may contribute to the objectives defined for the area analysed as a strategy for enhancing the acceptance of CEA as the future use of a structure. The specific improvements offered by such up-cycling are recognised as the key arguments when engaging with local authorities. A comparable conclusion, based on experience in developing agricultural practices in the urban environment, is illustrated in the report *Engaging with local authorities* (Davis, 2018) where the presentation of the key drivers for developing UA, as well as the definition of specific improvement measures and their relation to the targets defined in the current planning documents, are highlighted as the crucial opportunities for accepting CEA as the future use of the existing building. As a result, the majority of respondents indicated that the proposed up-cycling would be more viable when developed as a mixed-use building with facilities selected based on the requirements of a specific urban environment. However, from the urban farmers' standpoint, this approach would substantially limit the productivity of CEA, as the growing area is reduced due to the implementation of additional non-productive facilities. Therefore, several interviewees highlighted the development of uses compatible with UA as a significant secondary source of income (e.g. grocery, restaurant, farming and cooking school). The opportunities and limitations to meet the planning criteria which arose from the interviews are presented in Table 17.

Table 17: Planning criterion as a result of 15 semi-structured interviews; opportunities and limitations to meet these criteria, percentage of interviewees indicating these opportunities and limitations

CRITERION: The local authority must allow the up-cycling of inner-city modern movement car parking structure and accept CEA as future use					
	OPPORTUNITIES	%		LIMITATIONS	%
1	Improved social cohesion: - education, - job development, - community food growing, - space for social events	80	1	Approval of the change of use of a car parking structure for CEA: - lack of supportive policy, - lack of guidelines on the implementation of building-based CEA in urban planning documents, - UA not designated as a site allocation in land zoning	73.4
2	Improved health of urban residents: - improved access to nutritious food, - education on a healthy diet	93.4	2	Lack of knowledge on building-based CEA: - difficulties in assessing the social, environmental and economic performance of proposed adaptive reuse, - misunderstandings about transportation of the agricultural product, - assumptions about potential issues (e.g. noise, air and light pollution)	60
3	Space for innovations and research: - resource use efficiency, - nature-based solutions in urban areas, - innovative food production techniques, - circular economy, - food-water-energy nexus	60	3	Lack of space protection for UA: - meanwhile leases for CEA, - prioritising more cost-effective investments, - prioritising investment with higher social value	40
4	Long-term economic viability of the CEA operation: - adapted circular economy principles, - extended revenue opportunities, - involvement in collaborative marketing, - development of local distribution channels	53.4	4	Lower acceptance of CEA in cities than community food growing by: - decision makers, - urban residents	40
5	Reduced adverse environmental impact of the current food supply system and urban development: - reduced food miles, - lower pressure on agricultural land, - passive technologies, - synergies between CEA operation and other uses	60	5	High initial and operating costs of CEA: - hydroponic technology, - alternative energy technology options, - enclosing the space for CEA, -control of the internal environment parameters, - high demand for resources	33.4
6	Improved aesthetics of a car parking structure: - greening the building, - modernisation	40			

5.5.2. Architectural category of questions

The architectural value of inner-city modern movement car parking structures is perceived as high. The main argument for this is the availability of existing architectural space in a central urban district, which can be adaptively reused. The interviewees suggested lower initial costs for up-cycling, compared to demolition and new build, as the main benefit, which is also highlighted by Ball, 2002, Douglas (2006) and Kohler & Yang (2007). In the case of CEA in cities, repurposing urban structures is currently seen as the only realistic implementation option, due to the lower initial costs of development. These opinions are contrary to Despommier (2010, 2011) who stated that new buildings should be constructed for UA. The results of the interviews validate the conclusion of Al-Chalabi (2015) that the development of VF is a futuristic vision. The considerations of the architectural value of multi-storey garages during the interviews were linked to their adaptive reuse potential for CEA. Many respondents demonstrated the understanding that modern movement garages are challenging to repurposed as the primary architectural concept was focused on cars, and this fact has significantly influenced their design, including a lower floor-to-floor height than required for social uses (e.g. housing or offices). CEA is seen as a possible retrofit option which does not require many costly operations related to the structure of the building.

The interviewees linked the architectural value of multi-storey garages to environmental benefits. These themes were interrelated, owing to the understanding that the existing building stock is a resource that, when up-cycled, can make a significant contribution to the environmental sustainability of urban environments. When repurposing a multi-storey garage, the energy needed to build the space is decreased, while the embodied energy in the structure is maintained. These opinions referred to circular economy principles, where the adaptive reuse of buildings is strongly advocated as an operation that allows saving the embodied energy, preventing demolition energy and reducing material waste (Boschmann & Gabriel, 2013; Lehmann, 2016a; Velthuis & Spennemann, 2007; Wilkinson et al., 2009). In this context, the architectural value of multi-storey garages is comprised of the opportunity to repurpose these buildings as a strategy to reconcile the *architecture of the automobile* with a new environmental awareness, which in turn makes these structures obsolete.

The criticism voiced against the architectural value of inner-city car parking structures pointed at the priorities defined for the specific urban area, and stated that more social, environmental and economic benefits might be gained if these buildings are demolished and replaced by another investment. These opinions show that assessing and comparing the social, economic and environmental performance of an existing and a new building is crucial for the final decision on the future of the structure. Demolition and new construction are often considered a more straightforward solution, directly targeted at the current requirements of a specific urban environment. However, as reported by Bullen & Love (2010), Kohler & Yang (2007), Shipley, Utz, & Parsons (2006) incomplete data gathered for the value assessment often leads to the decision to demolish an obsolete structure. Therefore, the social, economic and environmental value of the proposed adaptive reuse should be carefully considered.

The discussions on the architectural modifications required for the adaptive reuse of modern movement garages for CEA led to the distinction between alterations to the structure, circulation, elevations, and the use of material for external cladding. The structural capacity of the building is a concern which needs to be addressed before up-cycling. Similarly, research by Jenkins (2018) and Sanyé-Mengual (2015) reported that a structural assessment is required to analyse the capacity of the accommodating architectural form, and to include structural alterations that reinforce the building. Structural elements, including concrete slabs and columns, although discussed by several experts, were not seen as a constraint for implementing CEA as the future use of the buildings analysed. However, the majority of interviewees perceived *the architecture of the automobile* as challenging to reuse for social uses (e.g. hotel or offices) and indicated that architectural decisions for repurposing the building with a mix of uses would require substantial structural modifications, especially those for a higher floor-to-floor height. Concerns which arose regarding the circulation were mainly focused on its efficiency. Additional heavy goods lifts and staircases may be needed for getting the agricultural product in and out of the garage.

The interviews revealed that a crucial architectural modification would be required for enclosing the space for creating a controlled environment for plant growth. The responses to this topic were divided into four scenarios. First, the installation of permeable external cladding material, glass or ETEF foil, to maximise sunlight transmission to the interior. This option would lead to the development of a PFSL within the multi-storey garage. Second, the placement of shipping containers within and upon the building as a PFAL. Third, the implementation of an RTG. Fourth, the least discussed option, the installation of an FF on the south façade of a garage. These CEA implementation options are consistent with the CEA types which arose in the literature review on building-based UA (e.g. Benis & Ferrão, 2018; Goldstein, Birkved, Hauschild, & Fernandez, 2014; Goodman & Minner, 2019; Kozai, 2013; Kozai, Niu, & Takagaki, 2015; Nadal et al., 2017; Pons et al., 2015; Sanjuan-Delmás et al., 2018; Sanyé-Mengual, Oliver-Solà, Montero, & Rieradevall, 2015; Shamshiri et al., 2018; Thomaier et al., 2014; Ting, Lin, & Davidson, 2016). However, the respondents did not provide specific data on the architectural form, orientation and materials advantageous for a CEA operation. Thus, for the next stage of research, this data will be sourced from the literature review (Chapter 4).

The discussions on the architectural modifications required for the adaptive reuse of inner-city modern movement garages for CEA operations indicated that the proposed up-cycling is seen as an opportunity for improving the aesthetics of these structures. Achieving this goal was mainly recommended by greening elevations and rooftops, as these alterations are perceived as a contribution to the green infrastructure that is in high demand in central urban districts. Classifying CEA as urban greenery can be interpreted as the generalisation of all forms of UA. However, the specificity of CEA substantially differs from traditional types of in-soil farming techniques. The development of CEA within multi-storey garages may be applied for the aesthetic improvement of this modern movement architecture (mainly through FFs and RTGs) however, to be classified as urban greenery, this strategy requires an innovative interpretation of green infrastructure. Further proposed alterations were associated with modernising the building, including the implementation of appealing frontages at the ground floor level, and the development of a volume as an extension of an existing garage for locating CEA installations. The scale of the proposed changes indicates that significant architectural modifications would be accepted to improve the aesthetics of inner-city modern movement car parking structures.

The modifications explored suggest that the crucial criterion for the adaptive reuse of an inner-city garage for CEA is that **the architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities.** The opportunities and limitations to meet these criteria which arose as results of interviews are presented in Table 18.

Table 18: Architectural criterion as a result of 15 semi-structured interviews; opportunities and limitations to meet these criteria, percentage of interviewees indicating these opportunities and limitations

CRITERION: The architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities					
	OPPORTUNITIES	%		LIMITATIONS	%
1	Flexibility of layouts for the functional arrangement of space for CEA including: - internal space (PFAL & PFSL), - external space (RTG & FF)	100	1	Structural conditions of the concrete building: - load-bearing capacity, - deflections and crackings	53.4
2	Modularity of layouts for the possibility to design modular hydroponic units and alternative energy installations which are easy to transport to another car parking structure: - repeatable plans, - repeatable parking bay dimensions: 2.4m x 4.8 m	53.4	2	Creation of the controlled environment in the car parking structure: - selection of technology to enclose the structure, - selection of infrastructure, which allows controlling different parameters of the internal environment	73.3

3	Accessibility for people and vehicles through existing: - ramps, - staircases, - lifts	26.7	3	Adaptation of the structural elements of a multi-storey garage for CEA installations: - floor-to-floor height, - distances between columns	53.4
4	Security: the structure can be easily closed to prevent breaking-in unauthorised access, theft and damage	13.4	4	Adaptation of circulation for CEA: - ramps, - staircases, - lifts	20
5	Improved aesthetics of the multi-storey garage: - greening the building, - modernisation	40	5	Fire safety	20

5.5.3. Environmental category of questions

Design for longevity, resistance and durability is the key goal that contributes to sustainable urban development. Owing to the constant evolution of cities and market demand for specific uses, many buildings are becoming derelict. Whether to demolish these structures or extend their life cycle through adaptive reuse becomes a crucial question, which can be answered through a comparative LCA of these two scenarios (Schwartz et al., 2018; Vilches et al., 2017). Up-cycling inner-city modern movement garages was seen as being of value in terms of environmental sustainability by the majority of interviewees. The main benefits arising from this process were associated with the maintenance of the embodied energy in the structure, and energy savings when comparing repurposing the building with demolishing it and building anew. These responses relate to the principles of the circular economy, where reduced environmental impacts are achieved through minimising the utilisation of virgin material, the production of demolition and construction waste, and the use of energy and transportation (Berg & Fuglseth, 2018; Bull et al., 2014; Gaspar & Santos, 2015; Hasik et al., 2019; Schwartz et al., 2018; Vandenbroucke et al., 2015; Vilches et al., 2017). This attitude, however, was presented only by architects and researchers, while the other respondents, although acknowledging the environmental value of the adaptive reuse of multi-storey garages, suggested that the environmental benefits arising from the proposed up-cycling might not outbalance the economic benefits of demolishing the building and replacing it with a new build. Prioritising economic opportunities over environmental values relegated the repurposing of car parking structures as a secondary strategy for urban development. Such an approach can hinder the investigation and mainstreaming into urban planning practice. As concluded by Bullen & Love (2010), assessing and comparing the environmental and economic performance of an existing and a new building is difficult, owing to the significant differences in space and technological solutions. The results which arose from the responses to this question confirmed the findings from the literature review that, from the perspective of decision makers, demolition and new construction are considered a more straightforward solution, directly targeted at market demand for modern spaces (Bullen & Love, 2010; Kohler & Yang, 2007; Shipley et al., 2006). This in turn can motivate architects and researchers to elaborate innovative design proposals for the up-cycling of *the architecture of the automobile*, leading to the decision to retain these structures as a contribution to environmental sustainability and reconciling these buildings with a new environmental awareness. The constant widespread researching and debating of these tensions can trigger innovative architectural solutions which are advantageous for urban environmental sustainability.

Building-integrated UA is perceived as an innovation and an experimental approach to food production in cities. CEA is associated with a high demand for urban resources, and for that reason developing a new structure for this function is considered not environmentally viable. The environmental burdens arising from the construction of a building for UA and the control of internal environmental parameters for crop cultivation are perceived as too high for justifying new development, for instance for VF or a PFAL. One respondent suggested that in the current stage of the development of building-integrated UA, its long-term viability is perceived as low, and therefore receiving funding for the construction of VF is not possible. Thus, the adaptive reuse of existing buildings, including car parking structures, is now the only environmentally viable strategy for the implementation of CEA within cities.

The high reliance of building-based CEA on urban resources was highlighted as the main reason for implementing resource-efficient technologies and alternative energy technology options in the process of up-cycling of multi-storey garages for CEA. Therefore, the responses to this category of questions revealed that the crucial criterion is that **the architecture of the modern movement car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of the CEA operation.** The opportunities and limitations to meet this criterion which arose in the interviews are presented in Table 19. The interviewees listed existing and emerging technologies, which would be required for water-saving and recycling, energy-saving and alternative energy generation. These technologies were linked with the emerging practice of developing synergies between CEA and the accommodating or neighbouring building in an urban environment (Ackerman et al., 2013; Specht et al., 2013). The literature supports such a strategy, indicating that the reduction of any adverse environmental impacts of building-based CEA should be the crucial point of the architectural exploration of the concept in its initial stage (Ackerman et al., 2013; Kozai, 2013, 2016; Ting et al., 2016).

The constraints arising from this category of question suggest that many technologies may not fit together with the existing infrastructure of modern movement multi-storey garages. While this limitation may be overcome by upgrading the installations within the building, such operations may substantially increase the initial costs of the development. Furthermore, high financial inputs are associated with the implementation of the alternative energy technology options discussed in the interviews. However, as highlighted by the literature (Ackerman et al., 2013; Al-Chalabi, 2015; Romeo et al., 2018) and six experts (40 percent), the development of technologies that allow minimising the use of urban resources and generating energy have arisen as an opportunity to justify the use of buildings for CEA, and to defray the associated costs of the operation over a long-term perspective.

While many of the technologies discussed are widely used, they have never been applied for provisioning the resource requirements of building-integrated CEA. For the majority of urban farmers, testing technological solutions is associated with too high a risk of financial consequences in the case of the experiment failing. Dealing with this issue may involve two strategies. First, engaging with a research institution, for instance as a part of the current research on the Urban Nexus relating to energy, water, food and waste/material flow (Bazilian et al., 2011; Lehmann, 2018). Second, obtaining grants focused on addressing environmental issues in the urban environment (e.g. water retention). The innovative solutions developed can form a substantial contribution to the research on architectural design aspects of building-based CEA and progress the existing building-based farming concepts of ZFarming , VF and BIA.

Table 19: Environmental criterion as a result of 15 semi-structured interviews; opportunities and limitations to meet these criteria, percentage of interviewees indicating these opportunities and limitations

CRITERION: The architecture of the modern movement car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of t**he** CEA operation					
	OPPORTUNITIES	%		LIMITATIONS	%
1	Resource-efficient technologies and alternative energy technology options: - optimal management of indoor microclimate, - energy-efficient lighting (LED lighting), - lighting control system, - regenerating alternative freshwater sources, - rainwater harvesting, - closed-loop plant cultivation system, - solar power systems (e.g. PV panels), - wind power systems	80	1	Innovative infrastructure may not be compatible with existing infrastructure in a multi-storey car parking structure	40

	(e.g. Wind Assured system), - ground sourced heat pump, - biomass				
2	Synergies between CEA and other uses: - exchange of energy, - exchange of water, - exchange of organic waste, - exchange of waste heat	40	2	High initial costs of the implementation of: - resource and energy-efficient technologies, - alternative energy technology options, - technical synergies	40
			3	Lack of innovative technologies required for developing synergies between CEA installations and additional uses	53.4

5.6. Summary of Chapter 5

What follows is a summary of the findings from the semi-structured interviews and their importance for the development of a guide for the analysis of the adaptive reuse potential of modern movement car parking structures for CEA.

Conclusions from the planning phase

- The adaptive reuse of inner-city car parking structures for CEA is not a familiar concept. The experts interviewed associate the use of space offered by multi-storey garages as an opportunity to increase and enhance urban food production as an economically viable business. However, the lack of expertise on the proposed up-cycling within the planning profession is a barrier for implementing the project, which is considered an innovation. Consequently, the secondary and primary data generated in chapters 4 and 5 should be included in the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA to provide knowledge for the design thinking process.
- The up-cycling of inner-city multi-storey garages for CEA is seen as an option on a temporary basis, specifically as a meanwhile lease before a more profitable investment is proposed. The guide should encourage innovative planning decisions regarding the location of CEA units and their implementation area to increase the social, economic and environmental viability of the proposed retrofit as a temporary use of inner-city modern movement garages.
- The local authority must allow for up-cycling inner-city modern movement car parking structures and accept CEA as a future use. Exploring current planning documents and identifying how the proposed up-cycling may contribute to the objectives defined for an urban area is recognised as a strategy for enhancing the acceptance of CEA as the future

use of modern movement garages. Consequently, the primary and secondary data on the potential planning opportunities and limitations for the proposed adaptive reuse for CEA from the stakeholders' perspective should be included in the guide to inform architects of the key drivers and motivations that can build a successful argument when engaging with a local authority.

- The up-cycling of car parking structures would receive more significant support from a local authority when proposed as a mixed-use development focused on urban food production. While the majority of experts highlighted a lower acceptance of repurposing inner-city buildings solely for CEA, the application of the guide should lead to the conceptualisation of potential uses, which are compatible with the objectives of the urban area analysed.

Conclusions from the architectural phase

- The architectural value of inner-city modern movement car parking structures is perceived as high due to the availability of architectural space in a central urban district. Repurposing this architectural type for CEA is associated with lower initial costs, and therefore is seen as the only viable option for developing building-integrated UA. The architectural and environmental values of inner-city garages are interrelated, owing to the understanding that the existing building stock is a resource that, when adaptively reused, can make a substantial contribution to urban environmental sustainability.
- The criticism voiced around the architectural value of inner-city modern movement car parking structures pointed at the priorities defined for the specific urban area, and stated that greater social, environmental and economic benefits might be gained if these buildings are demolished and replaced by new investments. Therefore, the application of the guide at the initial stage of the architectural process should gather data which can be used for a comparative value assessment of the proposed retrofit with demolition and new build, leading to a decision on the future of the car parking structure.
- The architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities. Consequently, the guide should point to specific features of modern movement garages and classify them as opportunities or limitations in order to assess the architectural modifications required for conceptualising the up-cycling potential of these buildings for CEA and associated facilities.
- Although the architectural value of modern movement car parking structures is not linked to their aesthetics, the discussions on the modifications required for up-cycling these garages for CEA suggest that improving their architectural appearance would

contribute to their positive perception within the built environment. Consequently, the guide should offer recommendations regarding the design opportunities and limitations for improving the aesthetics of the modern movement garages.

Conclusions from the environmental phase

- Up-cycling inner-city modern movement car parking structures is seen as being of value in terms of environmental sustainability by the majority of interviewees. However, environmental benefits brought about by repurposing these garages may not outbalance economic benefits if the building is demolished and replaced by a new build. The guide should offer innovative design insights for the adaptive reuse of *the architecture of the automobile,* which present a contribution to urban environmental sustainability and reconcile these buildings with a new environmental awareness.
- CEA is associated with a high demand for urban resources, and therefore developing a new structure for this function is considered not environmentally viable. The existing architecture and infrastructure of modern movement garages must allow for implementing resource-efficient technologies and alternative energy technology options in the up-cycling process in order to reduce the environmental impact of CEA installations. Consequently, the guide should identify the environmental opportunities and limitations for up-cycling modern movement car parks to inform architects of potential retrofit actions which increase the environmental viability of the proposed retrofit.

Synthesis of the results from the planning, architectural and environmental categories of questions

The analysis of the interviews revealed that the knowledge from the planning, architectural and environmental domains overlap in the experts' responses to the three categories of questions. In the planning phase, the architectural and environmental performance of the modern movement car parking structures was considered a foundation for investigating the viability of repurposing these buildings for CEA. The architectural and environmental dimensions became the sources of planning opportunities as well as limitations. The value of space in the inner-city offered by the existing structure was recognised as a possibility to accommodate uses required in the area for delivering social, economic and environmental benefits that may arise around urban food production from the planning perspective. Simultaneously, the architectural characteristics of the modern movement building developed for cars created several uncertainties regarding its up-cycling. These mainly evolved from the association of this architectural type with the original function, which predominated and constricted the conceptualisation of the use of the structure for a purpose other than car parking. Thus, the opinions expressed showed that from the planning point of view the adaptive reuse of modern movement garages is perceived as innovation, while retrofitting for CEA compounds the architectural and environmental uncertainties discussed in the further interview phases.

The possibilities identified within the planning domain of the proposed up-cycling for CEA informed the architectural phase of the interviews. The responses indicated that generating social, environmental and economic benefits requires recognising the opportunities and limitations arising from the architectural characteristics of modern movement garages. Their adaptation or alteration is the crucial criterion for the implementation and efficient operation of CEA installations and associated facilities. Moreover, the responses to the planning category of questions indicated a requirement to improve the architectural appearance of the concrete garages, while the opinions from the architectural phase explored and suggested solutions for such an improvement, which would contribute to their positive perception within the built environment. Moreover, the responses from the architectural category showed that the architectural and environmental values of inner-city car parking structures are interrelated, owing to the understanding that the existing building stock is a resource that, when repurposed, can make a substantial contribution to urban environmental sustainability.

The data obtained from the planning and architectural categories of questions offered crucial insights for the environmental phase. The modern movement structure is seen as a resource, and repurposing it with a different function is perceived as beneficial for the environmental sustainability of the urban area. In this context, the opinions from the architectural category informed how the modern movement typology can be altered to accommodate sustainable technologies and meet the demands of an alternative function as a response to changing urban needs. The opinions from the planning stage indicated that CEA is associated with high demand for urban resources. Thus, the opportunities and limitations for the implementation of resource-efficient and productive technologies has to be examined in order to minimise the adverse environmental impacts of this form of UA. The interrelatedness of the planning, architectural and environmental interview responses indicated the categories under which the modern movement car parking structure must be investigated when selecting it for analysis for potential up-cycling.

These results of the interviews defined the features which the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA should possess, and provided data crucial for the proposed retrofit. The following chapter will focus on the identification, description and conceptualisation of the guide, which can be used by architects for making informed design decisions when exploring the up-cycling potential of multi-storey garages for CEA.

Chapter 6: Guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for controlled environment agriculture

6.1. Introduction to Chapter 6

This chapter introduces the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA. The main aim of the tool is to enable the replication of the theoretical findings from this research in the process of exploring the up-cycling potential of these garages for CEA, and to lead the design thinking process when developing the initial design scenario. This can be achieved by applying the guide in the initial stage of the design to fulfil the planning, architectural and environmental criteria. The secondary data gathered through the review of the literature in Chapter 4 and the primary data obtained from the interviews with experts in Chapter 5 are the foundation for the development of the tool. The guide has subsequently been applied in Chapter 7 to explore three case studies, concerning their up-cycling potential for CEA operations.

6.2. Goal and scope of the guide

The purpose of this chapter is to develop a guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA operations. The overarching aim of the tool is to enable the replication of the theoretical findings from this research in the process of exploring the up-cycling potential of modern movement garages for CEA, and to lead the design thinking process when developing the initial design scenario. The guide points out planning, architectural and environmental criteria, steps and tools, as well as summarising and presenting data that allows for the architectural exploration of various scenarios for repurposing multi-storey garages for socially, environmentally and economically viable CEA operations. The tool is based on the primary data gathered through the interviews analysed in Chapter 5 and secondary data obtained through the literature review presented in Chapter 4, and has been validated through exploratory case study analysis. While the planning phase of the guide explores the urban dimension of the proposed up-cycling, the architectural and environmental phases investigate the concept on an architectural scale. The primary outcome of the guide is the conceptualisation of the initial design scenario for repurposing modern movement garages for CEA. The guide has been developed to be applied by architects in the initial stage of the design thinking process to collect data for further investigation of the concept, which is beyond the boundary of this thesis.

The recommendations for the guide's development which arose as conclusions from the analysis of the interviews were presented in Chapter 5.

6.3. The relevance of the guide arising from the literature review

Despite the evidence on the benefits of building-integrated UA in urban areas (Jenkins, 2018; Specht et al., 2013; Thomaier et al., 2014), there remains a paucity of criteria, procedures and tools to guide architects through the planning and design process leading to repurposing structures for socially, environmentally and economically viable CEA operations (Jenkins, 2018). In the context of the building stock initially designed for uses other than UA which become derelict due to changing market demand or economic issues, a lack of the data which is required for up-cycling constrains the management of the whole architectural process, including applying for the change of the use of the building, the development of the adaptive reuse proposal, and the selection of resource-efficient technologies and alternative energy technology options, and may lead to the rejection of the agricultural proposal (Sanyé-Mengual et al., 2016; Specht et al., 2015). This finding from the literature review pertains to multi-storey garages, designed for cars in the modern movement era, and their up-cycling for CEA operations. The conclusions from the interviews analysed in Chapter 5 indicated that the selected group of experts perceived the adaptive reuse of car parking structures for CEA as an innovation. As the number of redundant inner-city multi-storey garages is increasing (International Transport Forum, 2015; Zhang & Guhathakurta, 2017) due to the evaluation of private mobility concepts in central urban districts (Aftabuzzaman & Mazloumi, 2011; Brendel et al., 2018; Gössling, 2013; Inturri et al., 2017; Meyer, 1999; van Geet et al., 2019; van Wee et al., 2012), the development of the guide for the analysis of the up-cycling potential of these buildings for CEA aims to deepen the knowledge on this design problem. Applying this tool should lead to the initial design scenario conceptualisation as the first investigation stage, which creates the foundation for further steps in the research, and may result in the implementation of the project instead of demolishing the structure and replacing it with the new investment (beyond the boundaries of this thesis). The guide enhances the design thinking process on three levels: planning, architectural and environmental.

Within the planning context, in the research report *Engaging with local authorities,* Davis (2018) highlighted the importance of developing a plausible planning proposal, which distinguishes the key drivers and motivations to be presented when engaging with the local authority and applying for the change of use of the building. The literature review in Chapter 4 identified crucial opportunities for the implementation of building-integrated UA from the stakeholders' point of view (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015). Integrating these secondary data into the planning phase of the guide enables their interpretation within the planning objectives of the city as the primary arguments for up-cycling the car parking structure for CEA, and contributes to the discussion with the local authority on the proposed retrofit.

Concerning the architectural aspects of the adaptive reuse of buildings for CEA, Jenkins (2018) indicated a lack of replicable design data as the main limitation for repurposing structures with UA, as in each case the architect has to explore the concept from scratch. Chapter 4 revealed that the existing literature relevant to the design of viable CEA operations is extensive, however most of this data is neither summarised nor presented in the form of transferable knowledge. Thus, building-integrated UA operations which have been implemented are often based on a trial and error approach (Specht et al., 2013; Thomaier et al., 2014). From the perspective of an architect, such knowledge gaps hinder the conceptualisation of the up-cycling potential of modern movement garages for CEA. Therefore, the primary and secondary findings of this research have been adapted and integrated within the architectural phase of the guide to inform about the aspects crucial for the initial design scenario development.

While the literature review indicated the excessive use of resources as the main limitation for the environmental viability of building-based UF operations, much of the current literature pays particular attention to the investigation of resource-efficient and productive technologies which can be integrated into CEA operations (Kozai, 2016; Kozai, Niu, & Takagaki, 2015; Ting, Lin, & Davidson, 2016). Specht et al. (2013) highlighted that although many technologies are already available, much more research is needed to apply them in the context of a specific building in order to reduce the adverse environmental impact of CEA on the urban environment. Therefore, there is an urgent need to summarise the secondary data on sustainable technologies compatible with CEA which was explored in the literature review presented in Chapter 4, and use this knowledge when conceptualising the adaptive reuse potential of multi-storey garages for CEA. Applying this data in the environmental phase of the guide contributes to the development of a proposal for resource-efficient technologies and alternative energy technology options, which could be implemented when repurposing the inner-city car parking structure for CEA. Integrating the potential technologies within the up-cycling design scenario may become a strategy to reconcile the *architecture of the automobile* with a new environmental awareness, which in turn makes these structures obsolete.

When considering the future scenario of a derelict building, Bullen & Love (2010), Kohler & Yang (2007) and Shipley, Utz, & Parsons (2006) highlighted the incomplete data gathered for the value assessment as the primary constraint contributing to the decision for demolition. The guide developed in this chapter intends to generate data for the initial stage of the architectural process on planning, architectural and environmental solutions aimed at counteracting obsolescence, accommodating new functions, reducing the pressure on urban resources, and bringing aesthetic value to the urban environment. The knowledge on these aspects is of relevance for the comparative LCA of the proposed adaptive reuse for CEA compared to demolition and new build, now widely practiced when assessing the value of a future scenario for a derelict building in terms of environmental sustainability (Berg & Fuglseth, 2018; Bull et al., 2014; Gaspar & Santos, 2015; Hasik et al., 2019; Schwartz et al., 2018; Vandenbroucke et al., 2015; Vilches et al., 2017) energy maintenance and demand (Assefa & Ambler, 2017; Berg & Fuglseth, 2018; Bovea & Powell, 2016; Gaspar & Santos, 2015; Knoeri, Sanyé-Mengual, & Althaus, 2013; Lawania, Sarker, & Biswas, 2015; Ramesh, Prakash, & Shukla, 2010; Simion et al., 2013) and the potential for energy retrofit (Ghisellini, Ripa, & Ulgiati, 2018; Vandenbroucke et al., 2015; Vilches et al., 2017). The data gathered through the guide's application may be used to analyse the project complexity associated with the investment risk, highlighted as another limitation for retrofitting obsolete structures (Conejos et al., 2016; Ellison et al., 2007; Kurul, 2007). Therefore, the guide developed intends to gather data for the subsequent stages of this research.

6.4. Overview and scope of the guide

The guide consists of three phases, which are planning, architectural and environmental. For each phase a criterion has been developed, which is required to be accomplished to achieve the aim of the guide. The criteria arose from the results of the interviews in Chapter 5. Each phase consists of two steps. The interview results (Chapter 5) provided primary data relevant for accomplishing the first step of each phase, while the literature review gathered secondary data for fulfilling the second phase. The methodology for the guide's application was introduced in Chapter 2, Subsection 1.6.4. First, to meet the planning criteria, the planning phase identifies planning opportunities and limitations for the adaptive reuse of inner-city modern movement car parking structures for CEA, and formulates the key drivers and motivations, considered to be beneficial from the stakeholders' perspective, for the proposed up-cycling arising as a result of the planning documentation analysis. Second, to realise the architectural criteria, the architectural phase informs about design opportunities, and the limitations of such a retrofit arising from the interviews (Chapter 5), and summarises the data from the literature review (Chapter 4) on the design aspects beneficial for the development of the various viable CEA types within and upon multi-storey garages. Third, to accomplish the environmental criteria, the environmental phase lists environmental opportunities and limitations for the proposed up-cycling, and indicates resource-saving technologies and alternative energy technology options that in the process of the literature review were distinguished as being applicable to and advantageous for building-based UF.

6.4.1. Planning phase

The criterion for this phase: 'The local authority must allow the up-cycling of inner-city modern movement car parking structures and accept CEA as a future use' arose a result of the interviews with experts explored in Chapter 5. The planning phase of the guide was developed to investigate the concept of up-cycling inner-city modern movement garages for CEA operations on an urban scale. To meet the defined criterion, the architect should follow two steps of the guide. First, the identification of potential planning opportunities and limitations for up-cycling multi-storey garages for CEA. The aim of this step is to establish an understanding of the decision context. This is done through the planning policy analysis of selected cities, and the identification of critical development objectives as underlying policy statements. The exploration of the strategic documents focuses on linking the proposed retrofit with the objectives for the area being analysed by identifying how up-cycling the selected car parking structure for CEA may contribute to these improvements. For instance, the conclusions from this step may indicate the implementation of specific uses (e.g. farming school, community club), green jobs, new business opportunities, or greening the building. Furthermore, the first step of the planning phase identifies potential limitations for repurposing multi-storey garages for CEA which arise from the planning documentation, to inform architects on the constraints at the initial stage of proposal development. The second step focuses on the determination of the specific drivers and motivations for the adaptive reuse of the modern movement garage for CEA. This is done by linking the opportunities identified in the first step with findings from the literature review (Chapter 4) indicating the benefits of UA which are perceived as significant by the stakeholders. Accomplishing the planning phase of the guide leads to the identification of the key drivers and motivations for the adaptive reuse of inner-city modern movement car parking structures for CEA as arguments to be presented when engaging with a local authority and applying for the change of use of a building. Importantly, the planning phase collects data for the architectural and environmental phases, for instance regarding uses that need to be implemented alongside UA, or technologies required to contribute to the environmental goals of the area analysed. Planning data is crucial for making design decisions in the architectural and environmental phases of the guide.

6.4.2. Architectural phase

The criterion for this phase: 'The architecture of the car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities' is the crucial finding from the analysis of the second group of questions discussed during interviews, focused on the architectural design of modern movement garages. This phase of the guide explores the proposed adaptive reuse on an architectural scale. The data gathered in the planning stage of the guide, defined as the key drivers and motivations for the up-cycling process, should be applied in the architectural phase of the guide, for instance for making design decisions regarding the location of the uses distinguished in the planning phase (e.g. cooking school or restaurant). To meet the defined criterion, the architect should follow two steps. The first step focuses on the determination of potential architectural opportunities and limitations for the up-cycling under analysis. These data, explored through interviews with experts, are included in the guide in order to inform architects about the inherent possibilities and challenges that should be taken into consideration in the architectural phase of the proposal development. The first step of this phase should be accomplished through analysis of the plans of the selected car parking structure, and field observations for identifying the characteristics of the building and the urban context that affects architectural decisions. The first step should be conducted as an in-depth architectural investigation of layouts using design software. The second step focuses on the architectural exploration of design scenarios for developing CEA installations and the associated facilities strategically chosen in the planning phase of the guide. To achieve this goal, data is required which was gathered in the planning phase of the guide, the first step of the architectural phase and secondary data from the literature review. The analysis of this data allows for making informed design decisions regarding the selection or modification of the architectural form, orientation, cladding material and structure of the existing multi-storey garage, advantageous for plant cultivation as well as the resource-efficiency of the agricultural operation. This investigation should be done by using graphic design software, for instance Adobe Illustrator, Revit or Autocad. Accomplishing the architectural phase of the guide leads to the development of the initial architectural scenario for the adaptive reuse of the inner-city modern movement car parking structure for CEA. This phase gathers data for the environmental phase of the guide, for instance regarding cladding materials and their possible integration with PV panels. Thus, the architectural scenarios presented in this phase affect decisions in the third phase of the guide.

6.4.3. Environmental phase

The criterion for this phase: 'The architecture of the car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of the CEA operation' is the relevant finding from the analysis of the environmental group of questions discussed during the interviews. Data from the planning and architectural phases form the foundation for the environmental phase of the guide. While the environmental phase aims to investigate the concept on an architectural scale, the key environmental drivers and motivations arising from the planning phase have to be analysed through their relevance for this particular scale. The design scenarios developed in the architectural phase should be used as a basis for the proposal of resource-efficient technologies and alternative energy technology options in the environmental phase of the guide.

To meet the criterion defined in Chapter 5, the guide has two steps to be followed. First, the potential environmental opportunities and limitations for the proposed up-cycling should be determined through the framework of the findings of the planning phase of the guide. The specific opportunities and limitations identified by the experts during the interviews are presented in this step to inform architects about the technologies that should be considered for the proposed up-cycling. To accomplish this step, data from the planning and architectural phases should be analysed in design software, for instance Revit or Autocad. The data gathered affects design decisions in the second step of this phase: the selection of resource-efficient technologies and alternative energy technology options, which reduce the environmental impacts of CEA installations and minimise the use of urban resources. In this step, technologies relevant for CEA installations arising from the literature review (Chapter 4) are listed for the information of architects. Accomplishing the environmental phase of the guide leads to the development of the proposal for resource-efficient technologies and alternative energy technology options, which should be included in the initial design scenario for up-cycling the inner-city modern movement car parking structure for CEA.

6.5. Guide for the analysis of the adaptive reuse potential of modern movement car parking structures for controlled environment agriculture

- Planning phase: Figure 35,
- Architectural phase: Figure 36,
- Environmental phase: Figure 37.

PLANNING PHASE

CRITERION

The local authority must allow the up-cycling of the inner-city modern movement car parking structure and accept CEA as future use

TOOLS & DATA: Documentation review, Field observation

TYPE: QL, E

STEP 1

The analysis of the planning documentation concerning the selected inner-city area and the identification of the planning opportunities and limitations for repurposing the garage for CEA

OPPORTUNITIES

1. Improved social cohesion:
- education,
- job development,
- community food growing,
- space for social events.

2. Improved health of urban residents:
- improved access to nutritious food,
- educationon a healthy diet.

3. Space for innovations and research:
- resource use efficiency,
- nature-based solutions in urban areas,
- innovative food production techniques,
- circular economy,
- food-water-energy nexus.

4. Long-term economic viability of the CEA operation:
- adapted circular economy principles,
- extended revenue opportunities,
- involvement in collaborative marketing,
- development of local distribution channels.

5. Reduced adverse environmental impact of the current food supply and urban development:
- reduced foodmiles,
- lowered pressure on the agricultural land,
- passive technologies,
- synergies between CEA operation and other uses.

6. Improved aesthetics of a car parking structure:
- greening the building,
- modernisation.

LIMITATIONS

1. Approval of the change of use of a car parking structure for CEA:
- lack of supportive policy,
- lack of guidelines on the implementation of building-based CEA in urban planning documents,
- UA not designated as a site allocation in land zoning.

2. Lack of knowledge on building-based CEA:
- difficulties in assessing the social, environmental and economic viability of proposed adaptive reuse,
- misunderstandings about transportation of the agricultural product,
- assumptions about potential issues (e.g. noise, air and light pollution).

3. Lack of space protection for UA:
- meanwhile leases for CEA,
- prioritised more cost-effective investments,
- prioritisedinvestment with higher social value.

4. **Lower acceptance of CEA in cities than community food growing by:**
- decisionmakers,
- urban residents.

5. High initial and operating costs of CEA:
- hydroponic technology,
- alternative energy technology options,
- enclosing the space for CEA,
- controll of the internal environment parameters,
- high demand for resources.

STEP 2

The determination of the drivers and motivations for the adaptive reuse of the inner-city modern movement car parking structure for CEA arose from the analysis of the planning documentation

DRIVERS AND MOTIVATIONS

SOCIAL:

Improved transparency of food production,
Connection between consumers and food production,
Improved consumers` awareness
Improved food quality,
Nutrition-related health outcomes,
Improved community food security,
Educational opportunities,
Community building (empowerment, fun),
Spaces for experiments and creativity,
Improved living quality,
Improved physical activity levels.

ENVIRONMENTAL:

Reduced emissions and transport (food miles),
Improved organic waste recycling,
Improved water use efficiency,
Improved building energy efficiency,
Carbon and contamination fixation,
Reduced pressure on agricultural land,
Sustainable architecture and urban landscape,
Increased horticulture yields,
Enhanced closed cycles,
Naturalisation of the city.

ECONOMIC:

Adaptive reuse of derelict buildings and spaces,
Reduction of costs related to conventional agriculture,
Local economic development,
Potential products and high yields,
New business models,
income and employment,
Innovation to attract investors and showcase,
New marketing opportunities (e.g. new labels),
Availability of financial aid for new products,
Improved regional value chains.

TECHNICAL:

Improved urban self-sufficiency,
Adaptive reuse of buildings,
Experience in greenhouses and climatic architecture,
Energy-efficient productive architecture.

AESTHETICAL:

Improved building aesthetics,
Improved city landscapes.

PARTNERSHIPS AND POLICIES:

Improved public awareness,
New institutional supports and policies instituted for UA,
New inter-divisional, inter-governmental and/or cross-sectoral collaborations,
Cross-sectoral effects on poverty and health care costs.

Figure 35: Planning phase of the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA (Criterion can be Qualitative (QL) or Quantitative (QT) concerning the type of data required for validation; and External (E) or Internal (I)), if the criterion depends on external conditions or can be decided

ARCHITECTURAL PHASE

CRITERION

The architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities

TOOLS & DATA:
Architectural analysis, Architectural plans, Design & Graphic Software
TYPE: Q_L, Q_T, E, I

STEP 1

The identification of the architectural oppotunities and limitations for the adaptive reuse of the inner-city modern movement car parking structure for CEA

OPPORTUNITIES

1. Flexibility of layouts for the functional arrangement of space for CEA including:
- internal space (PFAL & PFSL),
- external space (RTG & FF).

2. Modularity of layouts for the possibility to design modular hydroponic units and alternative energy installations easy to transport to another car parking structure:
- repeatable plans,
- repeatable parking bays` dimensions: 2.4m x 4.8 m.

3. Accessibility for people and vehicles through existing:
- ramps,
- staircases,
- lifts.

4. Security:
the structure can be easily closed to prevent breaking-in unauthorised access, theft and damage.

5. Improved aesthetics of the multi-storey garage:
- greening the building,
- modernisation.

LIMITATIONS

1. Structural conditions of the concrete building:
- load-bearing capacity,
- deflections and crackings.

2. Creation of the controlled environment in the car parking structure:
- selection of technology to enclose the structure,
- selection of infrastructure, which allows controlling different parameters of the internal environment.

3. Adaptation of the structural elements of a multi-storey garage for CEA installations:
- floor-to-floor height,
- distances between columns.

4. Adaptation of circulation for CEA:
- ramps,
- staircases,
- lifts.

5. Fire safety

STEP 2

The architectural exploration of the various scenarios for the adaptive reuse of the inner-city modern movement car parking structure for CEA and associated facilities

TYPE	ARCHITECTURAL FORM	APPLICABLE	ADVANTAGES
RTG	**Single-span greenhouse**	YES	Lower initial costs related to the construction of a greenhouse;
	Uneven-span shape greenhouse	YES	Maximised solar radiation transmission; The highest internal air temperature among all shapes;
	Quonset shape greenhouse	YES	Reduced annual heating requirements compared to uneven-span gable roof shape; Can be built as a single-span greenhouse
	Multi-span greenhouse	YES	Reduced annual heating requirements compared to single-span greenhouse;
	Uneven-span shape greenhouse	YES	Can be built as a multi-span greenhouse; Improved energy efficiency of RTG
	Length-width ratio > 1 **Roof angle 25º-30º**	YES	Improved energy efficiency of RTG
FF	**Cavity between the layers of a double skin façade**	YES	Improved energy efficiency of the accommodating building
PFSL	**Existing building**	YES	Reduced initial investment associated with the construction of a new building; Potential in utilising a roof and facades for locating RTGs and FFs; Social and environmental symbiosis with other uses
PFAL	**Existing building** Warehouse-like structures	YES	Flexibility in the interior arrangement; Optimal management of the internal environment parameters; Potential in resource use efficiency
	Shipping container	YES	Modular farming space; Easy to multiply in urban settings

TYPE	ORIENTATION (LONGER AXIS)	APPLICABLE	ADVANTAGES
RTG	**EW**	YES	Maximised solar radiation transmission; Improved energy efficiency of RTG
FF	**S** **Any location in summer months**	YES	Maximised solar radiation transmission; Improved energy efficiency of FF and the accommodating building
PFSL	**NS**	YES	Maximised solar radiation transmission; Eluded main wind stream
	Growing installations located along east, south and west facades		Maximised solar radiation transmission
PFAL	-	NO	-

STEP 2

TYPE	CLADDING MATERIAL	APPLICABLE	ADVANTAGES
RTG	**Glass**	YES	Good solar radiation transmission; Good heat retention; Low transmission of UV light; Durability (long lifespan); Low maintenance costs; Possible integration with a PV system
	Semi-rigid plastics: Polycarbonate (PC)	YES	Good solar radiation transmission; Lightweight; Fire-law-compliant; Impact resistance; Hail resistance
	Polymethacrylate (PMMA)	YES	Good solar radiation transmission; UV filter (300 nm); Strong and lightweight; High corrosion resistance
	Plastic films Polyvinylchloride (PCV)	YES	Strong and lightweight; High resistance; Does not propagate the flame
	PE-based films (multilayer)	YES	Law-compliant only for walls; Low infiltration rate; Fair distribution of the transmitted light; Strong and lightweight; High resistance; Cheap
	Ethylene Tetrafluoroethylene Copolymer (ETFE)	YES	Fire-law compliant; Long lifespan; Lightweight; Fair distribution of transmitted light; UV filter; High corrosion resistance; High melting temperature; Flexible; Good solar radiation transmission
	Acrylic panel	YES	Good solar radiation transmission; Cheap
FF	**Glass**	YES	Good solar radiation transmission; Good heat retention; Low transmission of UV light; Durability (long lifespan); Low maintenance costs

STEP 2

TYPE	CLADDING MATERIAL	APPLICABLE	ADVANTAGES
PFSL	**Existing cladding material**	YES	Environmental benefits associated with the adaptive reuse of buildings: energy savings and the utilisation of existing materials; Good rating for insulation;
	Glass	YES	Good light transmittance; Good heat retention; Good acoustic performance; Low transmission of UV light; Durability (long lifespan); Low maintenance costs;
	EthyleneTetrafluoroethylene Copolymer (ETFE)	YES	Fire-law compliant; Long lifespan; Lightweight; UV filter; High corrosion resistance; High melting temperature; Flexible; High light transmittance; Excellent rating for insulation;
PFAL	**Existing *Thermally well-insulated and nearly airtight warehouse-like structure covered with opaque walls (Kozai, 2013, p. 448)***	YES	Environmental benefits associated with the adaptive reuse of buildings: energy savings and utilising existing materials; Good rating for insulation; Possible integration with a PV or wind power system
	Thermally insulated shipping container	YES	Good rating for insulation

TYPE	STRUCTURE	APPLICABLE	ADVANTAGES
RTG	**Multi-span**	YES	Larger distances between structural elements allow maximising the crop cultivation area;
	Structure of a roof	YES	Efficient load-bearing capacity to accommodate RTG
FF	**Double glazed façade**	YES	Efficient load-bearing capacity to accommodate FF
PFSL	**Existing structure**	YES	Larger distances between structural elements allow maximising the crop cultivation area
PFAL	**Existing structure**	YES	Larger distances between structural elements allow maximising the crop cultivation area

Figure 36: Architectural phase of the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA (Criterion can be Qualitative (QL) or Quantitative (QT) concerning the type of data required for validation; and External (E) or Internal (I), if the criterion depends on external conditions or can be decided internally)

E N V I R O N M E N T A L P H A S E

CRITERION

The architecture of the modern movement car parking structure must allow implementing resource efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of CEA

TOOLS & DATA:
Architectural plans, Field observation, Design Software
TYPE: Q_L, I

STEP 1

The identification of the environmental oppotunities and limitations for the adaptive reuse of the inner-city modern movement car parking structure for CEA

OPPORTUNITIES

1. Resource efficient technologies and alternative energy technology options:
- optimal management of indoor microclimate,
- energy efficient lighting (LED lighting),
- lighting control system,
- regenerating alternative freshwater sources,
- rainwater harvesting,
- closed-loop plant cultivation system,
- solar power systems (e.g. PV panels),
- wind power systems (e.g. Wind Assured system),
- ground sourced heat pump,
- biomass.

2. Synergies between CEA and other uses:
- exchange of energy,
- exchange of water,
- exchange of organic waste,
- exchange of waste heat.

LIMITATIONS

1. Innovative infrastructure may not be compatible with existing infrastructure in a multi-storey car parking structure

2. High initial costs of the implementation of:
- resource and energy efficient technologies,
- alternative energy technology options,
- technical synergies.

3. Lack of innovative technologies required for developing synergies between CEA installations and additional uses.

STEP 2

The analysis of application opportunities of resource efficient technologies and alternative energy technology options in the process of up-cycling the modern movement garage for CEA

TYPE	TECHNOLOGY
WATER SAVING AND RECYCLING	Closed-loop plant cultivation system Regenerating alternative freshwater sources Rainwater harvesting
ENERGY SAVING	**Closed or semi-closed greenhouses** **Synergies between UF and the accommodating building** Heat exchange Reuse of CO2 and O2 FF for cooling the building in summer and heating in winter **Energy-efficient electric devices** Energy efficient pumps and boilers Solid-oxide fuel cell LED lighting **Optimal management of indoor microclimate**
ALTERNATIVE ENERGY TECHNOLOGY OPTIONS	**BIPV** **GIPV** **BIWT** **Industrial waste heat exchange** **Geothermal energy** **Biomass**

Figure 37: Environmental phase of the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA (Criterion can be Qualitative (QL) or Quantitative (QT) concerning the type of data required for validation; and External (E) or Internal (I), if the criterion depends on external conditions or can be decided internally)

6.6. Limits of the guide

The guide is designed for architects working on the initial stage of a design scenario for the adaptive reuse of inner-city modern movement car parking structures for CEA. The application of the guide is limited to the initial phase of the design process. Further architectural decisions, beyond the scope of this thesis, should be made after consultation with discipline-specific experts, for instance structural engineers, horticulturists or experts in hydroponics. The main aspects which should be analysed during the following stages of the architectural process are summarised in Chapter 9, section 9.5. Continuing the investigation beyond the thesis boundaries is crucial for establishing the long-term viability of repurposing inner-city modern movement garages for CEA.

The limits of the tool developed may arise from the analysis of planning documents in the first phase, especially the lack of specific data on the improvements required in the area analysed. This may restrict the identification of the key drivers and motivations for the up-cycling process and substantially restrict the arguments to be presented when engaging with the local authority and applying for the change of use of the building. Another limit of the guide may be represented by the requirement to source the plans of the modern movement garages, necessary for conducting the architectural analysis in the second phase of the guide. Projects may be not available, timeworn or no longer current due to retrofits undertaken during the life cycle of the building. It may be necessary to involve the architect who developed the previous up-cycling design to obtain actual plans and deal with copyright laws.

6.7. Summary of Chapter 6

The purpose of this chapter was to develop the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA, which allows for the replication of the data generated in the theoretical phase of this thesis, leading to the conceptualisation of the initial up-cycling design scenario. This was done through pointing out the planning, architectural and environmental criteria, the steps and tools, as well as summarising and presenting primary and secondary data that contribute to the architectural exploration of the various scenarios for repurposing modern movement garages for viable CEA operations. The guide incorporates secondary data gathered through the literature review and validated through the exploratory case studies in Chapter 4, and primary data from the interviews in Chapter 5, for investigating criteria defined through the analysis of the interviews (Chapter 5) for the planning, architectural and environmental viability of the proposed retrofit. The expected users of the guide are architects in the initial stage of the design proposal conceptualisation. The data generated should be used for further concept development, beyond the boundaries of this thesis. In the next chapter, the guide will be applied to the explanatory case studies of three modern movement car parking structures in the UK.

Chapter 7: Application of the guide to the case studies. Investigating the viable adaptive reuse scenario of the three modern movement car parking structures for CEA.

7.1. Introduction to Chapter 7

In this chapter, the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA is applied to three strategically selected case studies of multi-storey garages located in Portsmouth, Bristol, and Brighton & Hove. While the tool was created to enable the replication of the theoretical findings from this research, and to guide the design thinking process, this part of the study has an explanatory character. It aims to investigate three case studies concerning their planning, architectural and environmental up-cycling potential for CEA, and specify the initial design scenario for their future. The proposals developed will be then analysed in Chapter 8 to discuss the adaptive reuse potential of inner-city modern movement garages for CEA, and evaluate alterations of this architectural type for accommodating an innovative use.

The investigation is placed within the existing buildings, which are regarded as having an architectural heritage capable of constituting the basis of the implementation of this scenario. In terms of architectural heritage, they have been analysed in terms of typology, namely their spatial schemes, and in terms of physical properties. For each urban environment analysed, the planning strategies determine the objectives for socially, economically and environmentally sustainable development. Thus, the adaptive reuse of the artefacts selected for each case study needs to be explored through the context of the aims of the specific city, taking into consideration the continuity of urban change and urban dynamics. The application of the guide is led by design thinking (Kimbell, 2012, 2015; Lawson & Dorst, 2009; Rowe, 1987; Schon, 1983), where the primary process investigating the future design scenario is the architectural analysis. According to Eisenman (1963), architectural systems evolve from external situations as well as internal functional requirements. Architectural analysis, therefore, allows us to investigate these systems as three-dimensional volumes developing in space and time, which are open to various internal and external forces leading to distortion and deformation (Eisenman, 2018). In this research, the architectural analysis of selected cases of inner-city modern movement garages is the key process aiming to explore the adaptive reuse scenario, which in the given dynamic urban and architectural context arises as a plausible strategy for the future of this architectural type, and within its capabilities addresses and respects the requirements of the city. According to these principles, the architectural analysis of the existing car parking structures investigates opportunities and limitations for repurposing them for CEA, which arose from the results of the interviews with experts (Chapter 5). The architectural analysis of the opportunities aims at highlighting:

- The flexibility of layouts: as an opportunity for the functional arrangement of space for CEA (PFAL, PFSL, RTG, FF),
- The modularity of layouts: as an opportunity to design modular hydroponic units and alternative energy installations which are easy to transport to another location,
- Accessibility: for people and vehicles for the efficient operation of the CEA system through existing ramps, staircases and lifts,
- Security: the possibility to secure the structure to prevent break-ins, unauthorised access, theft and damage to the CEA operation,
- Aesthetics: as an opportunity to improve the architectural appearance of the multi-storey garage through greening the building and modernisation.

The architectural analysis of the limitations aims at highlighting:

- Structural conditions: the analysis of the structural elements whose capacity needs to be assessed to determine the possibility to implement a CEA operation, including the required structural alterations that reinforce the building,
- Enclosing the car parking structure: rethinking the external cladding to create a controlled environment for plant growth,
- Adaptation of the structural elements: the analysis of the structural elements for selecting the location of the CEA operation within the existing structural form,
- Adaptation of the circulation: the investigation of the existing circulation in the context of the new function,
- Fire safety: the analysis of the evacuation routes regarding the requirements of the new use.

7.2. Case study 1: Portsmouth, Isambard Brunel Car Park (Fig. 38)

Figure 38: Isambard Brunel Car Park, Portsmouth, United Kingdom, Façade, Photo: Szopinska-Mularz 2019

7.2.1. Application of the planning phase of the guide

Criterion: The local authority must allow up-cycling the inner-city modern movement car parking structure and accept CEA as future use.

Step 1: The analysis of the planning documentation concerning the selected inner-city area and the identification of the planning opportunities and limitations for repurposing Isambard Brunel Car Park for CEA

The location of Isambard Brunel Car Park in the urban context is presented in Figure 39. The strategic planning documents selected for analysis include the City Centre Masterplan (Portsmouth City Council, 2013), the Portsmouth Plan. Portsmouth Core Strategy (Portsmouth City Council, 2012), the Portsmouth Local Development Scheme (Portsmouth City Council, 2019) and Food Growing SPD (Portsmouth City Council, 2015).

Figure 39: Location of Isambard Brunel Car Park in the urban context. Retrieved and adapted from https://digimap.edina.ac.uk, created 26 March 2018

The key objectives for the development of Portsmouth defined in the Portsmouth Plan (Portsmouth City Council, 2012) are:

1) *To make Portsmouth an attractive and sustainable city;*
2) *To make Portsmouth an accessible city with sustainable and integrated transport;*
3) *To develop Portsmouth as a city of innovation and enterprise, with a strong economy and employment opportunities for all;*
4) *To make Portsmouth a city in which everyone feels and is safe;*

5) *To deliver affordable/quality housing where people want to live;*
6) *To encourage and enable healthy choices for all and provide appropriate access to health care and support;*
7) *To enhance Portsmouth's reputation as a city of culture, energy and passion offering access for all to arts, sport and leisure*
8) *To ensure there is adequate supporting infrastructure for the new development and growth of the city* (Portsmouth City Council, 2012, p. 13)

These objectives are a foundation for exploring the planning opportunities and limitations for the adaptive reuse of the Isambard Brunel car parking structure for CEA in the first step of this phase of the guide. The other planning documents listed above provide supplementary data for the development of inner-city of Portsmouth, relevant for this analysis.

The opportunities and limitations listed in the first step of the planning phase of the guide can be identified in the first, third and sixth objectives defined in the Portsmouth Plan (Portsmouth City Council, 2012). Regarding the first objective, the architectural expectations for the future of Portsmouth concentrate on the implementation of quality architecture, protecting the local architectural heritage (Portsmouth City Council, 2012) and up-cycling the existing architecture (Portsmouth City Council, 2013). Repurposing Isambard Brunel Car Park with CEA would create an opportunity to preserve this structure as a quality piece of architecture from the modern movement era and improve the aesthetics of the building. The proposed up-cycling would bring social benefits in terms of the psychological reassurance of urban residents, since the character of a streetscape would be retained. Thus, the adaptive reuse of Isambard Brunel Car Park may contribute to an improvement in social cohesion in the inner-city, indicated in the first point of the opportunities listed in the planning phase of the guide. Considering environmental sustainability improvements within the first objective, greening the city through developing on brownfield areas and enhancing biodiversity is recommended in the City Centre Masterplan (Portsmouth City Council, 2013) and the Portsmouth Plan (Portsmouth City Council, 2012). A crucial goal is to apply sustainable design and construction techniques, as well as to exploit opportunities for incorporating renewable energy technologies (Portsmouth City Council, 2012):

as part of the city's bid to reduce its carbon footprint, new development will have to make the most of sustainable design and construction techniques as well as exploiting opportunities for generating and incorporating renewable energy technologies (Portsmouth City Council, 2012, p. 13).

Repurposing Isambard Brunel Car Park for CEA would contribute to the environmental goals of the city by linking urban greenery with architecture. This includes the introduction of innovative building-integrated green spaces, the improvement of urban biodiversity and a reduction in the carbon footprint of Portsmouth through utilising resource-saving techniques and renewable energy technologies. Point five of the opportunities listed for the first step of the planning phase corresponds with these improvements.

The third objective focuses on the enhancement of Portsmouth as a city of innovation and enterprise, with a strong economy and employment opportunities. The recommendations within this objective include specific uses: retail, business premises, cultural areas, restaurants, bars, cafes, tourist activities, and accommodation and city-centre living. Facilities required in the district analysed are listed explicitly in the City Centre Masterplan (Portsmouth City Council, 2013). They include offices, education and teaching accommodation, residential developments in the form of apartments or student accommodation. The document highlights the mixed-use development priority in the city centre, which allows for activities at different times of the day or night. These include uses which increase the liveliness of the area and improve community cohesion, for instance cafes and restaurants. Repurposing Isambard Brunel Car Park may contribute to these improvements if up-cycled as a mixed-use building. While the city is looking at opportunities for innovative businesses, the garage may be retrofitted for a food innovation centre, which focuses on mainstream research topics, for instance resource use efficiency, innovative soilless food production techniques, nature-based solutions, the food-water-energy nexus, or UA and circular economy principles. The implementation of such uses would correspond with point three of the opportunities listed in the planning phase. Based on the facilities considered in the planning documents analysed and those discussed with the experts, the proposed food innovation centre may be developed together with uses that provide education and guided tours focused on CEA, areas for social and cultural events, or restaurants. Integrating these uses creates opportunities for increasing the liveliness of the site and improving community engagement, thus corresponding with point one of the opportunities listed in the analysis phase.

As a significant objective of the strategy presented in the Portsmouth Plan (Portsmouth City Council, 2012) is to enhance the local economy and employment, CEA should be developed as a long-term economically viable business which provides new jobs. This may be done by adopting circular economy principles, involving collaborative marketing with farmers from the region and extending revenue opportunities by accommodating other businesses supportive of CEA, such as food processing or a restaurant. Developing distribution channels with local grocery businesses (Fig. 40) would further support up-cycling the inner-city garage for CEA. The planning opportunities indicated correspond with point four of the planning phase.

The sixth objective of the Portsmouth Plan (Portsmouth City Council, 2012) is focused on encouraging and enabling healthy choices for residents. Retrofitting Isambard Brunel Car Park for CEA may contribute to this goal by improving access to local, nutritious food for the community and offering educational programmes around a healthy diet. Considering these opportunities, the food innovation centre would enhance the transparency of food production and build a connection between consumers and producers, thus raising the awareness on the part of urban residents about food production techniques, the nutritional quality of purchased food and smart food choice, contributing in a long-term perspective to a reduction in diet-related issues. These improvements correspond with point two of the opportunities listed in the planning phase.

Figure 40: The distances between Isambard Brunel Car Park and large, medium and small grocery businesses located in the area. *Retrieved and adapted from https://digimap.edina.ac.uk, created 26 March 2018*

Regarding the limitations for the adaptive reuse of Isambard Brunel Car Park for CEA, some constraints may be found within the planning documents analysed. The most significant limitation is that Isambard Brunel Car Park is still required in the inner-city:

The Isambard Brunel multi-storey car park is an important facility within the Guildhall area and will be retained to serve existing and proposed development (Portsmouth City Council, 2013, p. 71).

Although in the future, the proposal for up-cycling this multi-storey garage for an alternative use may be needed, a retrofit is not currently under consideration.

Another limitation explored is that planning documents do not include building-based CEA as a site allocation, and prioritise uses with higher revenue opportunities in the inner-city (e.g. retail, businesses premises, restaurants, bars, tourist accommodation and city centre living). In this planning context, CEA could be accepted only as a green element of the existing architecture, for instance as an RTG or an FF. Furthermore, while the supplementary planning document Food Growing (Portsmouth City Council, 2015) offers some guidance on the integration of UA within the built environment, the paper does not provide information on CEA. The constraints identified are in line with those discussed by the experts during the interviews, listed in point one of the limitations in the first step of the planning phase.

Further issues which could arise when engaging with the local authority arise from a lack of knowledge on CEA and the perception of this form of UA operation as innovation. These limitations may include misunderstandings and assumptions on potential environmental problems associated with food production in the inner-city. For instance, the City Centre Masterplan (Portsmouth City Council, 2013) indicates the need to minimise noise transmission and vibration, light pollution and odours. As building-based CEA has not been yet developed in the inner-city of Portsmouth, the issues listed may become arguments to reject the CEA proposal. These challenges respond to the second limitation of the planning phase.

The lack of knowledge on the potential benefits of CEA for the city and its residents draws out further limitations, including the fact that the planning documents do not indicate space protection for any type of UA. While community food growing is encouraged and supported by the Food Growing SPD (Portsmouth City Council, 2015), the implementation opportunities are mainly identified within green infrastructure, or existing and new development in the form of in-soil UF techniques. This indicates a lower acceptance of CEA initiatives than traditional farming methods, caused by the fact that the social and environmental benefits of in-soil UA have already been explored and acknowledged, while a lack of expertise in CEA contributes to the perception of this type of UF as an innovation, and associates it with numerous uncertainties. As the interviews explored in Chapter 5 revealed, these uncertainties may include issues around the high initial costs of implementing hydroponic units, the control of the internal environment of the multi-storey garage for plant growth, as well as a high reliance on urban resources and the cost of technologies to reduce this. These challenges correspond with point five of the limitations listed in the first step of the planning phase.

Step 2: The determination of the drivers and motivations for the adaptive reuse of Isambard Brunel Car Park for CEA, arising from the analysis of the planning documentation

In this step of the guide, the data gathered in the previous step is linked to the key drivers and motivations for the implementation of CEA formulated in the literature review (Chapter 4). The drivers and motivations identified are organised in six thematic categories arising from the results of the interviews in Chapter 5. These categories are: (1) Improved social cohesion, (2) Improved health of urban residents, (3) Space for innovation and research, (4) Long-term economic viability of the CEA project, (5) Reduced adverse environmental impact of the current food supply system and urban development and (6) Improved aesthetics of a car parking structure. The results of step 2 are presented in Table 20.

Table 20: The determination of the potential drivers and motivations for the adaptive reuse of Isambard Brunel Car Park for CEA as a contribution to the objectives defined for Portsmouth in the planning documentation, planning phase of the guide's application, step 2

	Opportunities (interviews with experts)	**Objectives for the city defined in the planning documentation** (first step of the planning phase of the guide)	**Contribution of the adaptive reuse of the car parking structure for CEA to the priorities identified** (first step of the planning phase of the guide)	**Drivers and motivations** (literature review)
1	Improved social cohesion: - education, - job development, - community food growing, - space for social events	- to make Portsmouth an attractive and sustainable city,	- retaining the streetscape character through the adaptive reuse of the existing car parking structure, - providing educational opportunities and guided tours focused on CEA, - developing areas for social and cultural events, restaurants, bars or cafes, - offering green jobs	- adaptive reuse of derelict buildings, - educational opportunities, - community building (empowerment fun), - spaces for experiment and creativity, - improved public awareness

2	Improved health of urban residents: - improved access to nutritious food, - education on a healthy diet	- to encourage and enable healthy choices for all and provide appropriate access to health care and support	- locating food production in the inner-city of Portsmouth, - improving access to local, nutritious food for the community, - offering educational programmes on a healthy diet, - offering guided tours to the public	- improved transparency of food production, - connection between consumers and food production, - improved consumer awareness, - nutrition-related health outcomes, - cross-sectoral effects on poverty and health care costs
3	Space for innovations and research on: - resource use efficiency, - nature-based solutions in urban areas, - innovative food production techniques, - circular economy, - food-water-energy nexus	- to develop Portsmouth as a city of innovation and enterprise, with a strong economy and employment opportunities for all	- up-cycling the car park as a mixed-use building for a food innovation centre focused on mainstream research areas (e.g. resource use efficiency, nature-based solutions in urban areas, innovative food production techniques, circular economy, food-water-energy nexus)	- spaces for experiments and creativity, - innovation to attract investors and for showcasing
4	Long-term economic viability of the CEA project: - adapted circular economy principles, - extended revenue opportunities, - involvement in collaborative marketing, - development of local distribution channels	- to develop Portsmouth as a city of innovation and enterprise, with a strong economy and employment opportunities for all	- retrofitting the car parking structure as a mixed-use building, - adapting circular economy principles, - developing local distribution channels within Portsmouth, - involvement in collaborative marketing with other UA enterprises operating in the region, - extending revenue opportunities by accommodating other businesses	- reduction in costs related to conventional agriculture, - local economic development, - potential products and high yields, - new business models, income and employment, - new marketing opportunities, - improved regional value chains, - new inter-divisional and/or

			supportive for CEA (e.g. food processing, a restaurant)	cross-sectional collaborations
5	Reduced adverse environmental impact of the current food supply system and urban development: - reduced food miles, - lower pressure on agricultural land, - passive technologies, - synergies between CEA operation and other uses	- to make Portsmouth an attractive and sustainable city,	- implementing innovative building-integrated productive green spaces within the inner-city car parking structure, - improving urban biodiversity through growing plant species within and upon the car parking structure, - applying sustainable design and construction techniques for enclosing the space and developing CEA installations, - utilising resource-saving techniques and renewable energy technologies for reducing the reliance on urban resources by the CEA operation	- reduced emissions and transport, - improved water use efficiency, - improved building energy efficiency, - improved urban self-sufficiency, - reduced pressure on agricultural land, - sustainable architecture, - energy-efficient - productive architecture, - enhanced closed cycles, - experience in a greenhouse and climatic architecture
6	Improved aesthetics of a car parking structure: - greening the building, - modernisation	- to make Portsmouth an attractive and sustainable city,	- improving the aesthetics of a car parking structure, - preserving the modern movement architecture, - adaptive reuse of the car parking structure	- improved building aesthetics, - adaptive reuse of derelict buildings

7.2.2. Application of the architectural phase of the guide

Criterion: The architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities

Step 1: The identification of the architectural opportunities and limitations for the adaptive reuse of Isambard Brunel Car Park for CEA

The first step of the guide is the architectural analysis of Isambard Brunel Car Park and the critical evaluation of the findings from the perspective of an architect for the further development of the concept leading to the adaptive reuse of this multi-storey garage for CEA and additional facilities. The architectural analysis of Isambard Brunel Car Park focuses on the topic areas that arose from the interviews in Chapter 5 and is presented in Figures 41, 42, 43 and 44.

The following investigation presented in Figures 41 and 42 is conducted to address the architectural opportunities defined in the guide.

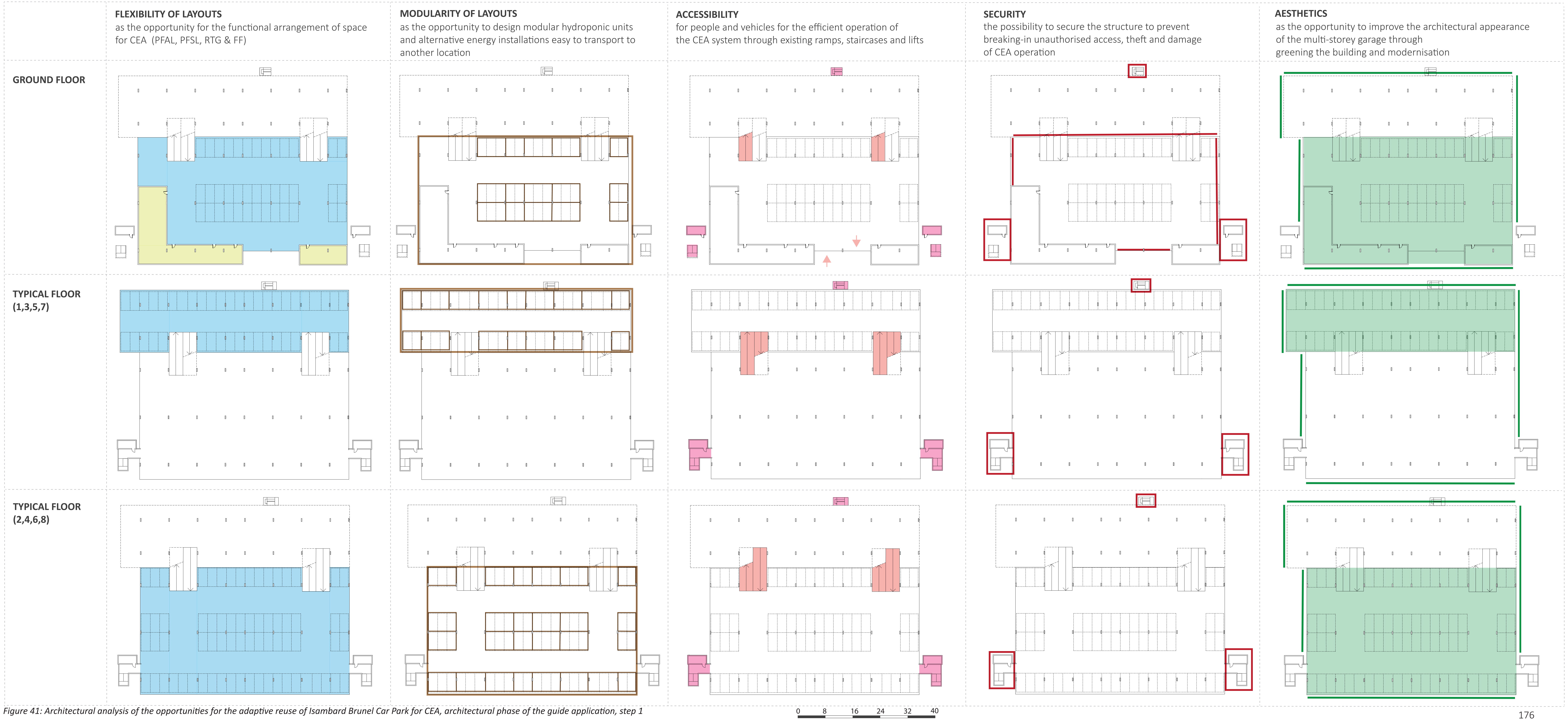


Figure 41: Architectural analysis of the opportunities for the adaptive reuse of Isambard Brunel Car Park for CEA, architectural phase of the guide application, step 1

Figure 42: Architectural analysis of the opportunities for the adaptive reuse of the Isambard Brunel Car Park for CEA, architectural phase of the guide application, step 1

The flexibility of layouts of Isambard Brunel Car Park is associated with the opportunity for the functional arrangement of space for CEA, including internal areas for a PFAL and a PFSL, as well as external areas for an RTG and an FF. The architectural analysis revealed that floors 1, 3, 5 and 7 offer identical potential in terms of the space arrangement. Similarly, levels 2, 4, 6 and 8 are repeatable. These areas are vertically divided by a regular grid of columns and ramps, and horizontally by concrete slabs. As there are no other architectural elements placed on these floors, the functional arrangement of space is flexible. The selection of the type of building-based CEA operation within these areas should be made considering the criteria given in the second step of the guide. The flexibility and repeatability of the layouts analysed allow for applying the strategy explored to design CEA units and multiply them vertically, thus developing VF, also referred to as a multi-storey PFSL (Graamans, Baeza, et al., 2017). The ground floor of the garage is currently used as an entry-level. with two enclosed spaces for staff and maintenance. The flexibility of this layout is constricted by existing walls and functions, which will be relevant after up-cycling Isambard Brunel Car Park for CEA, as it limits the implementation of hydroponic units. The rooftop of the garage consists of floor 8 and 9, connected by ramps due to the height difference between these levels. The architectural investigation shows that these levels offer high flexibility for space arrangement as they are not occupied by any solid elements, such as columns or walls. Thus, the rooftop potential may be used for designing a growing space and any additional uses arising from the planning phase of the guide. Another opportunity in terms of flexibility is identified on the elevations of the garage. As Isambard Brunel Car Park is a single function structure, the architectural strategy can be applied to utilise the elevations for CEA, taking into consideration requirements relevant for FFs highlighted in the second step of the guide.

The flexibility of layouts of Isambard Brunel Car Park is enhanced by their modularity. This includes the vertical modularity of floors as well as the horizontal modules created by the grid of columns, further divided into parking spaces as the basic module within each layout. The repeatability of the 1st, 3rd, 5th, 7th and 9th floors, as well as the 2nd, 4th, 6th and 8th floors, offers the opportunity to apply a similar architectural approach to design modular hydroponic units, which may be transported to a different location with the same module within Isambard Brunel Car Park, or to another multi-storey garage. The modularity of layouts allows for multiplying the growing units vertically, leading to the development of VF.

The accessibility of the car parking structure, associated with the presence of ramps developed for cars as well as staircases and lifts for people, was highlighted by the experts interviewed for this thesis as an opportunity to make the circulation of product and people efficient. In the case of the adaptive reuse of Isambard Brunel Car Park for food growing, the primary access to the structure is provided by the gate located on the south-west façade. The circulation of cars is continuous inside the structure through the internal system of ramps leading to the rooftop (9^{th} floor). Pedestrian access to all levels is provided by two external concrete staircases, and lifts located on the north-eastern and south-western elevations. Another staircase is located in the middle of the north-eastern façade. The architectural analysis of Isambard Brunel Car Park revealed that the existing ramps, stairs and lifts would provide efficient circulation for the needs of a CEA operation through providing accessibility for cars and people (staff members, visitors) to all levels.

The accessibility of Isambard Brunel Car Park is linked to the security of the garage. Securing the structure is required when implementing CEA and the uses distinguished in the planning phase of the guide to prevent unauthorised access. The analysis indicated that the ground floor layout should be enclosed, and should give access to authorised vehicles for the circulation of the agricultural product only. Circulation through the external staircases should be controlled on each level. While the areas of the multi-storey garage designated for social uses may be left open during working hours, the CEA area should be secured at all times to prevent theft, damage and the spread of disease.

The analysis of the aesthetics of Isambard Brunel Car Park revealed the need to amend the visual perception of the concrete garage. Improvements are required within the interior of the structure and its external skin. Transforming the internal space should be linked to the location and demands of specific uses, and include all levels of the garage. The architectural modifications to the elevations should focus on the north-eastern and south-western façades, as their visibility is emphasised in the surrounding built environment. These vertical surfaces offer opportunities to improve the acceptance of the concrete structure, and to increase the visibility of food production in the inner-city of Portsmouth. However, the modifications should be designed in a way that allows the retention of the character of the modern movement garage, and keeps its crucial architectural elements, including the external concrete staircases unique to Isambard Brunel Car Park.

The following analysis presented in Figures 43 and 44 was conducted to address the architectural limitations defined in the guide.

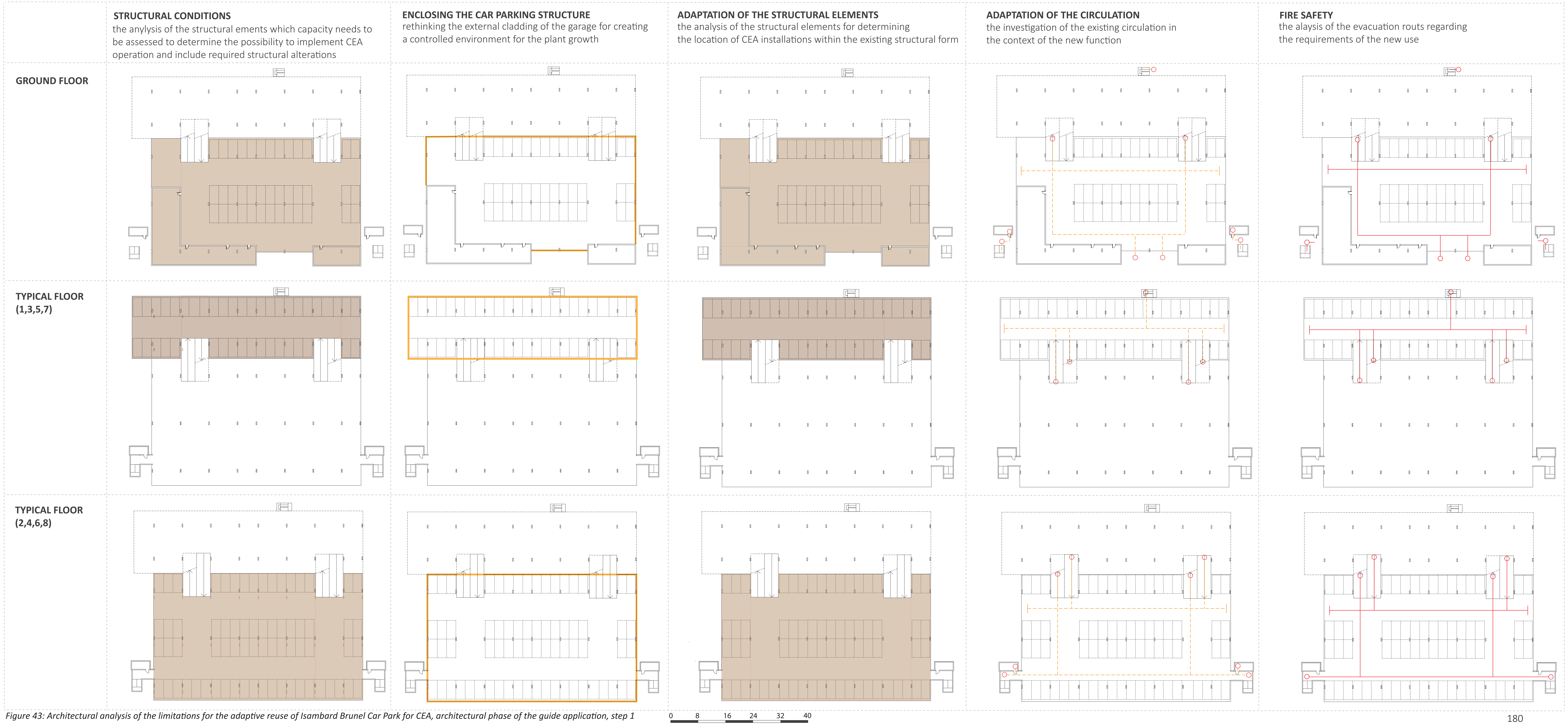


Figure 43: Architectural analysis of the limitations for the adaptive reuse of Isambard Brunel Car Park for CEA, architectural phase of the guide application, step 1

Figure 44: Architectural analysis of the limitations for the adaptive reuse of Isambard Brunel Car Park for CEA, architectural phase of the guide application, step 1

The first part of the architectural analysis revealed that the investigation of the structural conditions concerns concrete slabs and columns. Such an analysis is beyond the scope of this thesis, as a structural engineer should conduct this before the specific design is proposed. When exploring the limitations caused by the requirement to enclose the multi-storey structure, it is clear that creating a controlled environment entails the application of cladding materials on all four elevations. Depending on the orientation, some façades can be developed as FFs. The location of CEA on the rooftop of the Isambard Brunel Car Park requires implementing an RTG. The investigation on the structural elements indicated that the existing floor-to-floor height is not a limitation for the placement of hydroponic units. Nonetheless, it may become a constraint for further uses, particularly those accommodating a large number of people. Thus, the analysis should be repeated when making design decisions regarding the location of specific facilities in the next stage of the architectural proposal development, which is beyond the scope of this thesis. The exploration of the existing circulation within the garage showed that it is efficient for the proposed function. Vehicular access is provided through the internal ramps, while pedestrians can access through the external concrete staircases, and lifts located on the north-western and south-eastern elevations. However, a specific analysis should be conducted when making architectural decisions regarding the location of internal walls and doors to accommodate different uses, as this will affect the horizontal and vertical evacuation routes, and trigger the need to propose alterations for fire safety.

Step 2: The architectural exploration of various scenarios for the adaptive reuse of Isambard Brunel Car Park for CEA and associated facilities

In this step of the guide, the data collected in the first step of the architectural phase is evaluated in the context of the data gathered in the literature review (Chapter 4) regarding the parameters and elements that affect the selection of the type and location of productive space within and upon Isambard Brunel Car Park. This leads to the identification of the architectural approach that will develop the viable scenario for the design of the CEA operation and associated facilities within the analysed modern movement garage, presented in Figure 45.

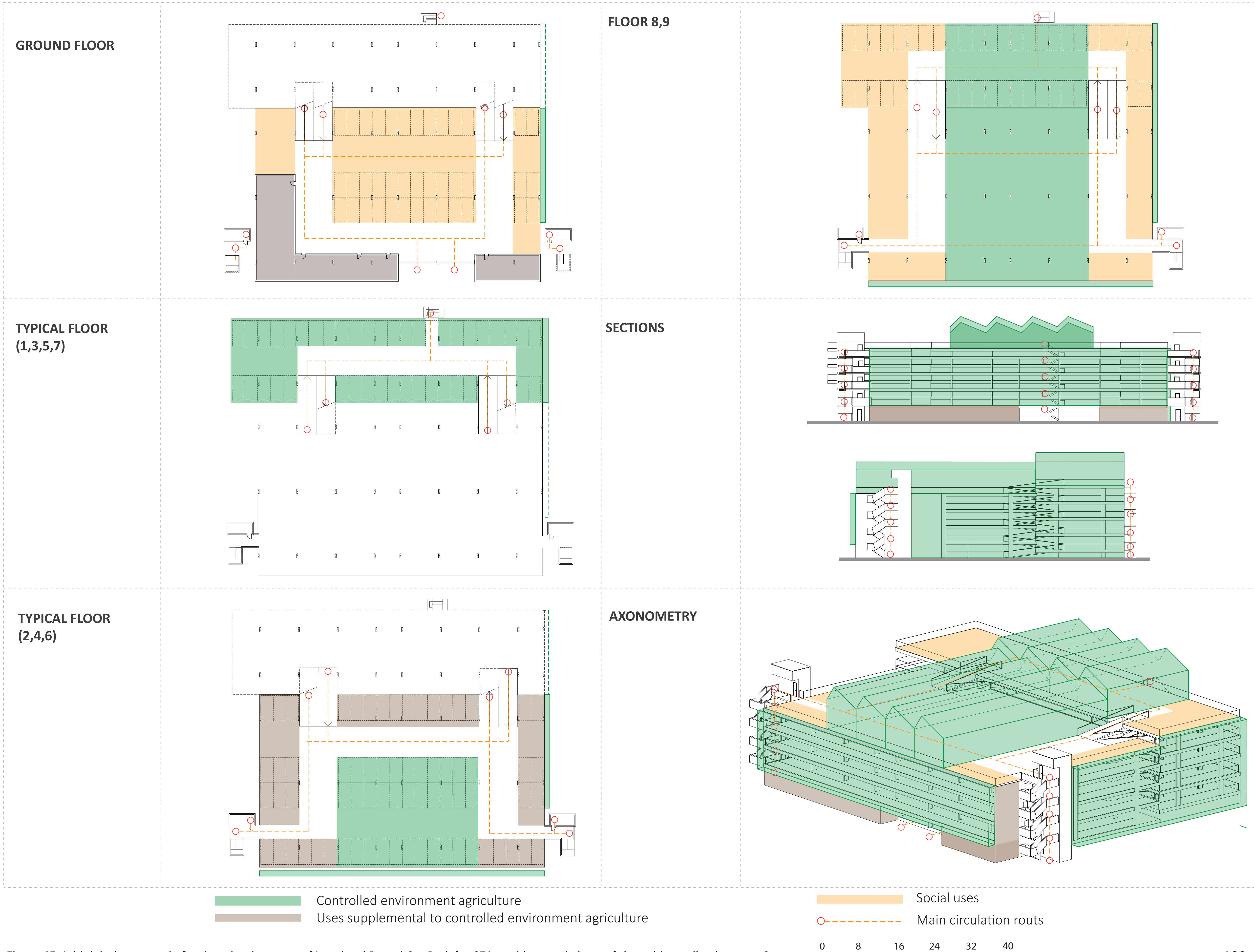


Figure 45: Initial design scenario for the adaptive reuse of Isambard Brunel Car Park for CEA, architectural phase of the guide application, step 2

The data obtained from the planning phase of the guide indicated that Isambard Brunel Car Park should be adaptively reused as a mixed-use building which focuses on local food growing, improving social cohesion, as well as innovation in local food production, distribution and consumption in the inner-city area of Portsmouth. The architectural analysis revealed that the ground floor should be mainly used for accessing the structure and enhancing the connection with the surrounding urban environment through developing social uses, for instance a restaurant, café and social and cultural event space. The ground floor should accommodate a food innovation centre within the existing enclosed spaces. The location of social uses and innovative businesses working in the food industry on the same level of the car parking structure would offer flexibility on the level of public involvement in the food innovation centre's activities. The main vehicular entrance to the garage should be retained, while the location of entrances for pedestrians should be located considering the requirements of specific uses.

Levels 2, 4 and 6 should be divided for CEA and the food innovation centre. The location of the hydroponic installations at the south-western façade would allow the utilising of sunlight for food growing, thus leading to the development of VF as a PFSL. The food innovation centre would benefit from natural light access from the north-west and south-east. To control the internal environmental parameters, glass cladding or ETFE foil should be used for enclosing the internal space for the mixed-use building. The regular grid of columns designates a module for placing hydroponic units within this area of Isambard Brunel Car Park. Vehicular access to the levels analysed is provided through internal ramps, while pedestrians can access through external concrete staircases, and lifts located on the north-western and south-eastern elevations.

Levels 1, 3, 5 and 7 are recognised as the areas with the highest opportunity for developing the CEA operation owing to the availability of sunlight from the north-western, north-eastern and south-eastern elevations, and the much lower width of the layout compared to its length, which allows for maximising the transmission of solar radiation to the interior. This favourable location for the food growing units is recognised as an opportunity to develop a PFSL as the most viable design scenario, owing to the lower energy use for lighting (Çakir & Şahin, 2015; Kozai et al., 2015; Nadal, Alamús, et al., 2017) and increased productivity of an agricultural system lit by sunlight (Jenkins, 2018). This would require enclosing the space by using glass cladding or ETFE foil. However, the installation of permeable materials to create a controlled environment for plant growth increases the initial financial investment, which, especially in the case of temporary up-cycling for UF, may be too high. Therefore, a second approach would be to use shipping containers and multiply them vertically and horizontally within the levels analysed, thus developing a PFAL without the need for enclosing the garage. Finally, the car parking structure can be enclosed with solid materials to develop a PFAL. Existing structural elements offer the possibility to design modular hydroponic units and vertically multiply them within the analysed area. Levels 1, 3, 5 and 7 are accessible through ramps, and the steel staircase attached to the north-east façade.

The potential of the rooftop area (level 8 and 9) should be utilised for developing an RTG. The analysis shown that this type of CEA operation should be located in the central area of the roof, as that offers the opportunity to orientate the longer axis of the greenhouse along the east-west axis and achieve a length-width ratio higher than 1, thus maximising the transmission of solar radiation and contributing to the energy efficiency of this CEA operation. The width of the RTG is restricted by the existing ramps, and the length by the dimensions of the garage. The rooftop offers the spatial possibility to increase the crop cultivation area by implementing a multi-span greenhouse as an uneven-span shape greenhouse, which according to the literature review is the most energy-efficient option in the temperate climatic zone. The potential materials for the external skin of the RTG include glass, semi-rigid plastics, plastic films and acrylic panels. Owing to the requirement to improve the aesthetics of Isambard Brunel Car Park, the use of glass or ETFE foil is recommended. The north-western and south-eastern areas of the rooftop could be designed for social purposes, for instance a restaurant, space for social events or workshops. Vehicular access to the RTG would be provided through ramps, while pedestrian access to the social areas would be through staircases, and lifts located at the north-western and south-eastern elevations.

The architectural investigation revealed the opportunity to develop an FF on the south-western and south-eastern elevations of Isambard Brunel Car Park. These locations maximise the transmission of solar radiation required for crop cultivation, thus increasing the productivity potential of FFs, especially in colder months. Implementing an FF requires enclosing the multi-storey garage by installing double glazed glass façades with integrated food cultivation units. As the analysis showed that the aesthetics of Isambard Brunel Car Park should be improved, this operation would contribute to the modernisation and greening of the concrete structure, as well as the enhancement of the visibility of UA in the inner-city. The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the internal and external areas of Isambard Brunel Car Park is shown in Tables 21 and 22.

Table 21: The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the internal area of Isambard Brunel Car Park

	Area [m²]				
Level	CEA	Uses supplemental to CEA	Social uses	Circulation	Total area
0	0	321.2	912.9	626.6	1860.7
1	690.6	0	0	348.3	1038.9
2	610.9	680.6	0	673	1964.5
3	690.6	0	0	348.3	1038.9
4	610.9	680.6	0	673	1964.5
5	690.6	0	0	348.3	1038.9
6	610.9	680.6	0	673	1964.5
7	690.6	0	0	348.3	1038.9
8	972.6	0	500.1	491.8	1964.5
9	477.4	0	391.2	170.3	1038.9
Total	6045.1	2363	1804.2	4700.9	14913.2
%	40.50%	15.90%	12.10%	31.50%	100%

Table 22: The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the external area of Isambard Brunel Car Park as FFs

	Vertical area [m²]	
Elevation	FF	Total area
NE	0	854
SE	519.6	673.2
NW	0	673.2
SW	566	724
Total	1085.6	2924.4
%	37.10%	100%

7.2.3. Application of the environmental phase of the guide

Criterion: The architecture of the modern movement car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of the CEA operation

Step 1: The identification of the environmental opportunities and limitations for the adaptive reuse of Isambard Brunel Car Park for CEA

In this step of the environmental phase of the guide, data from the planning phase is used as the basis for investigating opportunities and limitations for implementing resource-efficient technologies and alternative energy technology options in the process of up-cycling the multi-storey garage for a CEA operation. The results of the planning phase of the guide revealed that the crucial environmental drivers and motivations for the adaptive reuse of Isambard Brunel Car Park for CEA are clustered around the aim to reduce the adverse environmental impact of the current food supply system and urban development. While the planning phase of the guide focuses on the urban scale of the adaptive reuse of inner-city car parking structures for CEA, the environmental phase of the guide explores the architectural scale of the concept. The specific drivers and motivations distinguished in the planning phase, relevant from the architect's perspective in the initial stage of the design proposal development, include improved water use efficiency, improved building energy efficiency, sustainable architecture, energy-efficient productive architecture and enhanced closed cycles. In this step of the environmental phase of the guide, these drivers and motivations are linked to the environmental opportunities and limitations defined in Chapter 5.

The first opportunity identified in the guide is to implement resource-efficient technologies and alternative energy technology options in the process of up-cycling Isambard Brunel Car Park for a CEA operation. This includes the optimal management of the indoor microclimate, installing energy-efficient lighting (LED lighting) and a lighting control system, regenerating alternative freshwater sources, rainwater harvesting, solar power systems (e.g. PV panels), wind power systems (e.g. Wind Assured system), ground sourced heat pumps, using biomass and developing a closed-loop plant cultivation system. The second opportunity identified is to create technical synergies between the CEA operation and other uses located within and upon Isambard Brunel garage. Such a symbiotic relationship may enable the exchange of energy, water, and heat, and the reuse of CO_2 and O_2. These opportunities contribute to improved water use efficiency, building energy efficiency and enhanced closed cycles as the key drivers and motivations relevant for the architectural scale of the proposed adaptive reuse. Applying these technologies would allow up-cycling the modern movement garage as an energy-efficient productive and sustainable architecture, which reduces the adverse environmental impact of CEA associated with an excessive reliance on urban resources.

The application of the defined opportunities may be limited by a lack of compatibility between innovative technologies and the existing infrastructure in Isambard Brunel garage. Another constraint may be a lack of innovative technologies required for developing synergies between CEA installations and other uses. The high initial costs of resource and energy-efficient technologies, alternative energy technology options and technical synergies are identified as a limitation that may significantly reduce the installation the technologies identified. These constraints may create a barrier for the adaptive reuse of Isambard Brunel Car Park as an energy-efficient productive and sustainable architecture.

Step 2: The analysis of opportunities for applying resource-efficient technologies and alternative energy technology options in the process of up-cycling Isambard Brunel Car Park for CEA

The design scenario for the adaptive reuse of Isambard Brunel Car Park for a CEA operation, developed in the architectural phase of the guide, is the foundation for exploring the opportunities for applying resource-efficient technologies and alternative energy technology options in this step of the environmental phase of the guide. First, for water-saving and recycling, a closed-loop plant cultivation system should be developed in a PFSL or a PFAL, occupying the designated internal areas of the Isambard Brunel Car Park, the multi-span RTG and FFs. Regenerating alternative freshwater sources should be applied within all types of CEA operation. The rooftop area of the multi-storey garage offers the spatial potential for locating rainwater harvesting installations. Second, for energy saving, energy-efficient electric devices should be used within the CEA operation, including energy-efficient pumps and boilers, solid-oxide fuel cells and LED lighting systems. The RTG should be developed as a closed or semi-closed greenhouse. The indoor microclimate within all CEA types proposed in the architectural phase of the guide should be optimally managed. As Isambard Brunel Car Park is a single function structure, the technical synergies can be developed solely between the CEA operation and other uses implemented while retrofitting the structure as a mixed-use building. These include heat exchange, reuse of CO_2 and O_2, as well as installing FFs for providing thermal comfort within the garage. Third, alternative energy technology options should be installed within and upon the multi-storey structure to reduce the reliance of the CEA installations on urban resources. An opportunity for developing BIPV has been identified on the south-western and south-eastern elevations. While these external areas of Isambard Brunel Car Park are allocated for FFs, (architectural phase of the guide), BIPV should be integrated with the double-glazed façades which accommodate FFs. GIPV should be installed as a replacement to elements of the external cladding of the multi-span RTG. Another opportunity for improving the building's self-sufficiency is associated with the installation of BIWT. Energy may be produced by a large-scale wind turbine located on the rooftop of the garage, or many small-size wind turbines on a roof of the building or the façade. The second opportunity is to directly utilise the skin of the building or an exterior wall which is a large, unused area subject to wind pressure, as the system developed by Park et al. (2015) or the Wind Assured system indicated by one of the experts in Chapter 4. Further alternative energy technology options which should be considered include the industrial heat exchange between the CEA operation and other uses located within Isambard Brunel Car Park or neighbouring buildings, geothermal energy and biomass use. The specific site analysis, technical details and spatial opportunities for implementing these technologies should be investigated after the architectural project is proposed at the next stage of research, which is beyond the boundaries of this thesis.

7.3. Case study 2: Bristol, Prince Street Car Park (Fig. 46)

Figure 46: Bristol Hotel and Prince Street Car Park, Bristol, UK, Façade. Photo: Szopinska-Mularz 2019

7.3.1. Application of the planning phase of the guide

Criterion: The local authority must allow the up-cycling of inner-city modern movement car parking structures and accept CEA as a future use

Step 1: The analysis of the planning documentation concerning the selected inner-city area and the identification of the planning opportunities and limitations for repurposing Prince Street Car Park for CEA.

The location of Prince Street Car Park in the urban context is presented in Figure 47. The strategic planning documents selected for the analysis include the Bristol Development Framework. Core Strategy (Bristol City Council, 2011), Bristol Central Area Plan (Bristol City Council, 2015b), Site

Allocations and Development Management Policies Local Plan (Bristol City Council, 2014) and the Conservation Area Enhancement Statement (Bristol City Council, 1993).

Figure 47: Location of Prince Street Car Park in the urban context. Retrieved and adapted from https://digimap.edina.ac.uk, created 26 March 2018

UA in Bristol is considered in planning documents either as a temporary site allocation within brownfield sites, or a permanent element of buildings as green infrastructure, for instance green roofs, roof gardens and living walls (Bristol City Council, 2011). Food growing as a possible site allocation within the city's green infrastructure is supported by the Bristol Development Framework (Bristol City Council, 2011). Policy DM15: Green Infrastructure Provision (Bristol City Council, 2014) indicates that new residential developments should offer the opportunity for local food growing, while policy DM29: Design of New Buildings (Bristol City Council, 2014) expects new construction to incorporate green infrastructure as green walls, green roofs and green decks, which may be used as potential spaces for UF. The implementation of UA is mainly associated with new residential developments, where facilities for local food growing are strongly encouraged (Bristol City Council, 2019). Building-integrated CEA is not included in the planning documentation of Bristol.

The key objectives for the development of Bristol defined in the Bristol Development Framework Core Strategy (Bristol City Council, 2011) are:

1) *Ensuring a sustainable future for Bristol,*
2) *Mixed, balanced and sustainable communities,*
3) *Ambitious and sustainable economic growth,*
4) *Appropriate housing provision,*
5) *Better health and wellbeing,*
6) *High quality-built environment,*
7) *High-quality natural environment,*
8) *Improved accessibility and connectivity,*
9) *Effective waste management,*
10) *Adapting to climate change and promotion of renewable energy,*
11) *Community involvement and engagement* (Bristol City Council, 2011, p. 24)

These objectives are the foundation for exploring the opportunities and limitations for repurposing Prince Street Car Park for CEA in the first step of the planning phase of the application of the guide. The other planning documents listed above provide supplementary data for the development of inner-city of Bristol, relevant for this analysis.

The opportunities and limitations listed in the first step of the planning phase are identified in the first, second, third, fifth, sixth and tenth objectives defined in the Bristol Development Framework Core Strategy (Bristol City Council, 2011). Considering the first objective, the policy (Bristol City Council, 2011) gives priority to sustainable development and growth aimed at meeting the needs of the city now and in the future. This objective can bring multiple opportunities for up-cycling Prince Street Car Park for CEA. First, as repurposing derelict buildings is now considered the most sustainable approach to urban development (Lehmann, 2016a, 2017), design for adaptability is highlighted in Site Allocation and Development Management Policies (Bristol City Council, 2014), which indicate that new buildings are expected to:

Allow for future adaptation or extension to accommodate alternative uses or to respond to the changing future needs or circumstances of occupiers by means of their internal arrangement, internal height, detailed design and construction (Bristol City Council, 2014, p. 61).

Fundamental values for the environmental sustainability delivered by up-cycling Prince Street Car Park may include the prevention of the loss of embodied energy and the generation of demolition energy, as well as a reduction in material waste. These benefits correspond with point five of the opportunities listed in the first step of the planning phase. Second, within economic sustainability, the retrofit analysed would require lower initial financial investment compared to a new development for CEA. Thus, the proposed up-cycling could become a way of testing the economic viability of innovative building-based CEA from a long-term perspective with lower initial investment needed. This contribution to the first objective corresponds with point four of the opportunities listed in the first step of the planning phase of the guide. Finally, within the social dimension of urban sustainability, up-cycling a building located in the old city enables the retention and protection of the unique character of the place. While the aesthetics and continuity of the urban fabric play a crucial role in shaping the attitudes and behaviours of the local community and visitors (Jacobs, 1961; Lynch, 1960), repurposing Prince Street Car Park would preserve the character of the streetscape, thereby enhancing the psychological reassurance of urban dwellers (Ball, 2002; Bullen & Love, 2010; Douglas, 2006). Thus, the adaptive reuse of this inner-city modern movement garage may be of considerable cultural, historical and architectural value, which maximises the social profitability of the existing structure and urban district. These benefits are linked to the first opportunity from the first step of the planning phase.

Within the second objective defined by Bristol City Council (2011), priority is given in Bristol to mixed-use development to provide a high-quality environment for balanced and sustainable communities. Mixed-use buildings comprising offices, retail, residential, leisure, entertainment, tourism and cultural facilities with active ground floor uses are supported by the Bristol Development Framework Core Strategy (Bristol City Council, 2011), Bristol Central Area Plan (Bristol City Council, 2015b) and the Site Allocations and Development Management Policies Local Plan (Bristol City Council, 2014). Within this objective, the opportunity for repurposing Prince Street Car Park was identified when the process led to the implementation of a mix of uses supportive of CEA. For instance, the Site Allocations and Development Management Policies (Bristol City Council, 2014) highlighted the role of existing markets in the city centre of Bristol, and a need for new proposals for markets and market-related development in the area. The adaptive reuse of Prince Street Car Park as a mixed-use building developed around food production could accommodate such uses, thus contributing to a reduction in food miles through local distribution of the food produced.

Prince Street Car Park is adjacent to the Bristol Hotel, which offers opportunities to develop a functional connection between CEA and the hotel's facilities. This relationship may arise from the requirements defined in the Bristol Central Area Plan (Bristol City Council, 2015b),, which calls for new leisure uses which enhance the relationship between the harbour and the historical function of the area. As Prince Street Car Park is located directly on the river Avon, to justify its adaptive reuse, new uses on the ground floors would have to reinforce the connection to the dockside and introduce new leisure opportunities attractive for pedestrians and cyclists. The potential facilities could include retail, entertainment, tourism, and cultural spaces as a link between the CEA operation and the Bristol Hotel. For instance, the location of educational facilities, including school and workshop areas or cultural spaces within the multi-storey garage, would benefit the liveability of the city centre and encourage tourists and residents to engage within UA. Thus, the contribution to this objective corresponds with points one, two and four of the opportunities listed in the first step of the planning phase.

When analysing the opportunities for the proposed up-cycling within the third objective (Bristol City Council, 2011), it becomes clear that repurposing Prince Street Car Park may contribute to the sustainable economic growth of Bristol when developing a CEA operation as a viable business over a long-term perspective. While the critical goal defined within this objective is ensuring the economic competitiveness of the district through new development and regeneration, developing CEA on a commercial scale may benefit this objective when applying strategies recommended by the experts in the interviews. This includes adopting circular economy principles, extending revenue opportunities by implementing facilities supportive for CEA, involving in collaborative marketing with UF within the region, and developing local distribution channels. Repurposing the multi-storey garage for a mix of uses should offer new jobs, skills, training and education on CEA as a form of innovative employment and business in the city. These goals correspond with point four of the objectives defined in the guide. Furthermore, up-cycling Prince Street Car Park for CEA may contribute to the ambitions of Bristol for innovative businesses. The proposed up-cycling could be developed as a business incubator, gathering entrepreneurs involved in food businesses, for instance delivering innovative local food production and distribution techniques within the city (Fig. 48). In this context, repurposing Prince Street Car Park contributes to point three of the opportunities defined in the first step of the planning phase.

The fifth objective calls for improving green infrastructure, developing high-quality leisure, tourism and culture facilities, which are accessible by public transport, walking and cycling. This objective aims to enhance quality of life and reduce pollution, leading to better health and wellbeing for urban dwellers. The opportunities for up-cycling Prince Street Car Park arising from this objective include the enhancement of the green infrastructure through the location of various CEA types within and upon the multi-storey garage. Opening CEA for the public through guided tours, workshops, and activities for the local community and tourists focused on quality food growing, cooking and eating could bring about positive health outcomes and improve the well-being of the local community. Thus, these improvements apply to the first and second opportunities in the first step of the planning phase.

Figure 48: The distances between Prince Street Car Park and large, medium and small grocery businesses located in the area. Retrieved and adapted from https://digimap.edina.ac.uk, created 26 March 2018

The sixth objective highlights the importance of delivering attractive and safe places with a high-quality build environment. According to the Conservation Area Enhancement Statements (Bristol City Council, 1993), Queen Square and Prince Street were created in 1700 at the junction of the River Frome and the River Avon. The neighbourhood now belongs to a conservation area. However, the conservation document indicates that Prince Street Car Park is perceived as a post-war development which distorts the perception of the neighbourhood, as it does not respect scale, height and historic street pattern (Bristol City Council, 1993):

The former, amongst the largest early residential Georgian Squares in the country, contains almost in its entirety buildings of distinction, now marred by unsightly forecourt car parking, whilst in *contrast, the latter has lost much of its fine character through low-quality post-war development* (Bristol City Council, 1993, p. 16).

Repurposing the garage would offer the opportunity to improve the perception of this modern movement structure by implementing an alternative function, which affects the aesthetics of the building. This may be done by greening the external skin of the structure, for instance through an FF and an RTG, and modernising the building. The benefits identified contribute to point six of the opportunities defined in the first step of the planning phase.

The tenth objective defined within the Bristol Development Framework (Bristol City Council, 2011) focuses on addressing the causes of climate change by prioritising sustainable construction techniques and renewable energy generation. If deciding to up-cycle Prince Street Car Park for CEA, the embodied energy would be retained and material waste would be prevented. Further benefits for the environmental sustainability of the urban environment would be delivered by local food production and supply, which lowers the pressure on agricultural land and reduces the food miles required to supply foods produced within the global food system to Bristol. When repurposing the multi-storey garage for CEA, resource-efficient technologies and renewable energy production methods should be applied. The use of such technologies would offer an opportunity to reduce the reliance of the CEA operation on urban resources. These environmental benefits correspond with point five of the opportunities listed in the first step of the planning phase.

When analysing the limitations for the adaptive reuse of Prince Street Car Park for CEA, the first constraint arises from the fact that, although planning documentation supports building-integrated UA (Bristol City Council, 2011, 2014), it does not mention CEA as a possible site allocation by itself, but links it with new development and green infrastructure as a facility which brings benefits to the community. Thus, UA is seen as an opportunity to involve urban residents and improve community cohesion, rather than enhancing the local food supply within Bristol. This constraint corresponds with the first and third points of the planning limitations. As the analysis of the interviews with the experts (Chapter 5) concluded, this is due to a lack of expertise in building-based CEA, which lowers the acceptance of this type of UF and prioritises traditional community food growing. This constraint is identified within point four of the planning phase. The lack of knowledge of CEA makes the assessment of the social, economic and environmental performance of the proposed adaptive reuse difficult. Thus, up-cycling Prince Street Car Park for CEA may be questioned regarding its social, economic and environmental validity in the inner-city area.

The lack of expertise in building-integrated CEA may raise concerns regarding the potential adverse environmental impacts caused by the proposed up-cycling, for instance, noise, air and light pollution. While Prince Street Car Park is located within the Old Town, this site is designated as an Air Quality Management Area, where exposure to noise-sensitive development is aimed to be minimised (Bristol City Council, 2015b). This issue corresponds to the second point of limitations listed in the first step of the planning phase. Further constraints relate to the economic viability of the operation. While the first and third objectives defined in the Bristol Development Framework (Bristol City Council, 2011) focus on economic development, the financial viability of the proposed building-based UF may be questioned due to the high initial and operating costs of CEA. This includes investment in implementing hydroponic installations and alternative energy technology options, enclosing the space for CEA and controlling the internal environmental parameters, as well as high demand for resources raising the costs of this type of local food production. These issues apply to point five of the planning limitations.

Step 2: The determination of the drivers and motivations for the adaptive reuse of Prince Street Car Park for CEA arising from the analysis of the planning documentation

In this step of the planning phase of the guide, the data gathered in the previous step is linked to the key drivers and motivations for the implementation of UA formulated in the literature review (Chapter 4). The drivers and motivations identified are organised in six thematic categories arising from the results of the interviews with the experts presented in Chapter 5. These categories are: (1) Improved social cohesion, (2) Improved health of urban residents, (3) Space for innovation and research, (4) Long-term economic viability of the CEA project, (5) Reduced adverse environmental impact of the current food supply system and urban development and (6) Improved aesthetics of a car parking structure. The results of step 2 are presented in Table 23.

Table 23: The determination of the potential drivers and motivations for the adaptive reuse of Prince Street Car Park for CEA as a contribution to the objectives defined for Bristol in the planning documentation, planning phase of the guide's application, step 2

	Opportunities (interviews with experts)	Objectives for the city defined in the planning documentation (first step of the planning phase of the guide)	Contribution of the adaptive reuse of the car parking structure for CEA to the identified priorities (first step of the planning phase of the guide)	Drivers and motivations (literature review)
1	Improved social cohesion: - education, - job development, - community food growing, - space for social events	- ensuring a sustainable future for Bristol, - mixed, balanced and sustainable communities, - better health and wellbeing	- retaining and protecting the unique character of the place, - up-cycling the multi-storey garage as a mixed-use development (e.g. market place, school, workshop,	- adaptive reuse of buildings, - educational opportunities, - community building (empowerment fun),

			restaurant, gallery or exhibition space), - providing educational opportunities and guided tours focused on CEA, - developing areas for social and cultural events, restaurants, bars or cafes, - offering green jobs	- spaces for experiment and creativity, - improved public awareness, - improved living quality, - new business models, income and employment
2	Improved health of urban residents: - improved access to nutritious food, - education on a healthy diet	- mixed, balanced and sustainable communities, - better health and wellbeing	- placing food production in the inner-city of Bristol, - improving access to local, nutritious food to the community by developing the market place and related facilities, - offering educational programmes and workshops on a healthy diet, - offering guided tours to the public	- improved transparency of food production, - connection between consumers and food production, - improved consumer awareness, - nutrition-related health outcomes, - cross-sectoral effects on poverty and health care costs, - improved urban self-sufficiency
3	Space for innovations and research on: - resource use efficiency, - nature-based solutions in urban areas, - innovative food production techniques, - circular economy, - food-water-energy nexus	- ambitious and sustainable economic growth	- developing CEA as an innovative business, - up-cycling the multi-storey garage for a business incubator for enterprises focused on innovations in UA (e.g. resource use efficiency, nature-based solutions in urban areas, innovative food production techniques, circular economy, food-water-energy nexus)	- new business models, income and employment, - improved regional value chains, - innovation to attract investors and for showcasing, - local economic development, - new inter-divisional, inter-governmental and/or cross-sectoral collaborations
4	Long-term economic viability of the CEA project:	- ensuring a sustainable future for Bristol,	- lowering initial financial investment compared to the	- reduction in costs related to

	- adapted circular economy principles, - extended revenue opportunities, - involvement in collaborative marketing, - development of local distribution channels	- mixed, balanced and sustainable communities, - ambitious and sustainable economic growth,	development of new building for CEA, - testing the economic viability of innovative building-based CEA operation, - adapting circular economy principles, - extending revenue opportunities by implementing facilities supportive for CEA operations (e.g. market place, school, workshop, guided tours, restaurant, art and exhibition space), - involvement in collaborative marketing with farmers from the region, - developing local distribution channels in Bristol, - generating new jobs, skills training and education on CEA, - developing a functional connection between the CEA operation and the Bristol Hotel	conventional agriculture, - local economic development, - potential products and high yields, - new business models, income and employment, - new marketing opportunities, - improved regional value chains, - new inter-divisional and/or cross-sectional collaborations
5	Reduced adverse environmental impact of the current food supply system and urban development: - reduced food miles, - lower pressure on agricultural land, - passive technologies, - synergies between CEA operation and other uses	- ensuring a sustainable future for Bristol, - adapting to climate change and the promotion of renewable energy	- preventing embodied energy loss and demolition energy generation, reducing material waste, - lowering the pressure on agricultural land, - reducing food miles required to supply foods produced within the global food system to Bristol, - reducing the adverse environmental impact of the development by implementing resource-efficient	- reduced emissions and transport, - improved water use efficiency, - improved building energy efficiency, - improved urban self-sufficiency, - reduced pressure on agricultural land, - sustainable architecture, - energy-efficient productive architecture,

			technologies and renewable energy production methods	- enhanced closed cycles, - experience in a greenhouse and climatic architecture
6	Improved aesthetics of a car parking structure: - greening the building, - modernisation	- high quality-built environment	- greening the external skin of the building (e.g. by implementing FFs and RTGs), - preserving the modern movement architecture, - modernising the car parking structure	- improved building aesthetics, - adaptive reuse of derelict buildings

7.3.2. Application of the architectural phase of the guide

Criterion: The architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities

Step 1: The identification of the architectural opportunities and limitations for the adaptive reuse of Prince Street Car Park for CEA

The first step of this phase of the guide focuses on the architectural analysis of Prince Street Car Park, and the critical evaluation of the findings from the perspective of an architect for further developing the concept leading to the adaptive reuse of this multi-storey garage for a mixture of uses gathered around a CEA operation. The architectural analysis of Prince Street Car Park investigates the topic areas arising from the interviews presented in Chapter 5.

The analysis which follows in Figures 49 and 50 was conducted to address the architectural opportunities defined in the guide.

Figure 49: Architectural analysis of the opportunities for the adaptive reuse of Prince Street Car Park for CEA, architectural phase of the guide application, step 1

Figure 50: Architectural analysis of the opportunities for the adaptive reuse of Prince Street Car Park for CEA, architectural phase of the guide application, step 1

The flexibility of layouts of Prince Street Car Park is associated with an opportunity for the functional arrangement of space for CEA, including internal space for a PFAL and a PFSL, as well as external space for an RTG and FFs. The investigation revealed that floors 2, 4, 6, 8 and 10 offer the same opportunities for the arrangement of space. Similarly, levels 1, 3, 5, 7, and 9 are repeated. These areas are vertically divided by ramps, and horizontally by concrete slabs. The crucial vertical structural element is the concrete wall located along the central axis of the multi-storey garage, which allows the support of all floors of the building without the need for developing other vertical structural elements, for instance columns. The absence of a grid of columns offers high flexibility for spatial arrangement. Thus, the flexibility and repeatability of the layouts investigated provide an opportunity to design CEA units and multiply them vertically. This leads to the development of VF as a multi-storey PFSL or PFAL. As Prince Street Car Park is spatially and functionally connected to the Bristol Hotel, this limits flexibility in the arrangement of the internal and external space of the structure. The ground floor is used as an entry-level to the multi-storey garage and for hotel facilities. The flexibility of this layout is constricted by the existing function, which should be retained. Similarly, the connected rooftops of Prince Street Car Park and the Bristol Hotel are occupied by the glass structure used for the hotel's purposes. Thus, the ground floor and the rooftop of Prince Street Car Park cannot be allocated for CEA operations. Opportunities in terms of flexibility for implementing CEA on the elevations of the building have been identified on the western and eastern façades. The architectural strategy which should be applied to utilise these external areas for CEA needs to be developed after evaluating requirements relevant for an FF in the second step of the guide.

The flexibility of layouts in Prince Street Car Park is enhanced by their modularity. This includes the vertical modularity of floors as well as the module created by the plan of parking bays. The repeatability of the 3rd, 5th, 7th, and 9th floors, as well as the 2nd, 4th, 6th, 8th and 10th floors, offers the possibility to take a similar architectural approach leading to the design of modular hydroponic units, which may be transported to another location with the same module within Prince Street Car Park, or to another multi-storey garage if required. The modularity of layouts allows for multiplying the growing units horizontally and vertically, which leads to the development of VF.

The accessibility of the car parking structures is associated with efficient vehicular access provided by ramps, as well as pedestrian access through staircases and lifts. In the case of Prince Street Car Park, the main gate for vehicular access is located on the eastern façade. The circulation of cars is continuous inside the structure through an internal system of ramps leading to the 10th floor. Pedestrian access to all levels is provided by two internal staircases, the first attached to the north elevation and the second placed between the garage and the hotel. There is one lift providing access to the 2nd, 4th, 6th, 8th and 10th floors.

The accessibility of Prince Street Car Park is linked to the security of the garage. Up-cycling the structure for mixed-use development requires securing the building to prevent unauthorised access. The architectural analysis revealed that the main vehicular gate should be enclosed, and give access to authorised vehicles for the circulation of agricultural products only. The entrance through the internal staircases should be controlled at the ground floor level. As the areas of the multi-storey garage designated for social uses may be open during working hours, the CEA area should be secured at all times to prevent theft, damage and the spread of disease.

Investigating the aesthetics of Prince Street Car Park revealed a need to amend the visual perception of the interior of the concrete structure. The modernisation of the internal space should be linked to its location and the requirements of specific facilities, and include all levels currently used as a garage. The patterns developed on the elevations of Prince Street Car Park represent a unique concrete geometric composition, which is recommended to be retained as a relic of modern movement architecture in the central area of Bristol. These vertical surfaces may be utilised to increase the visibility of inner-city food production, for instance by greening the building through an FF. However, the modifications should be designed in a way that retains the character of the modern movement garage and keeps its crucial architectural elements, especially the concrete X components on the east and west façades.

The analysis which follows in Figures 51 and 52 was conducted to address the architectural limitations.

STRUCTURAL CONDITIONS
the anylysis of the structural ements which capacity needs to be assessed to determine the possibility to implement CEA operation and include required structural alterations

ENCLOSING THE CAR PARKING STRUCTURE
rethinking the external cladding of the garage for creating a controlled environment for the plant growth

ADAPTATION OF THE STRUCTURAL ELEMENTS
the analysis of the structural elements for determining the location of CEA installations within the existing structural form

ADAPTATION OF THE CIRCULATION
the investigation of the existing circulation in the context of the new function

FIRE SAFETY
the alaysis of the evacuation routs regarding the requirements of the new use

GROUND FLOOR

TYPICAL FLOOR (2,4,6,8,10)

TYPICAL FLOOR (3,5,7,9,11)

Figure 51: Architectural analysis of the limitations for the adaptive reuse of Prince Street Car Park for CEA, architectural phase of the guide application, step 1

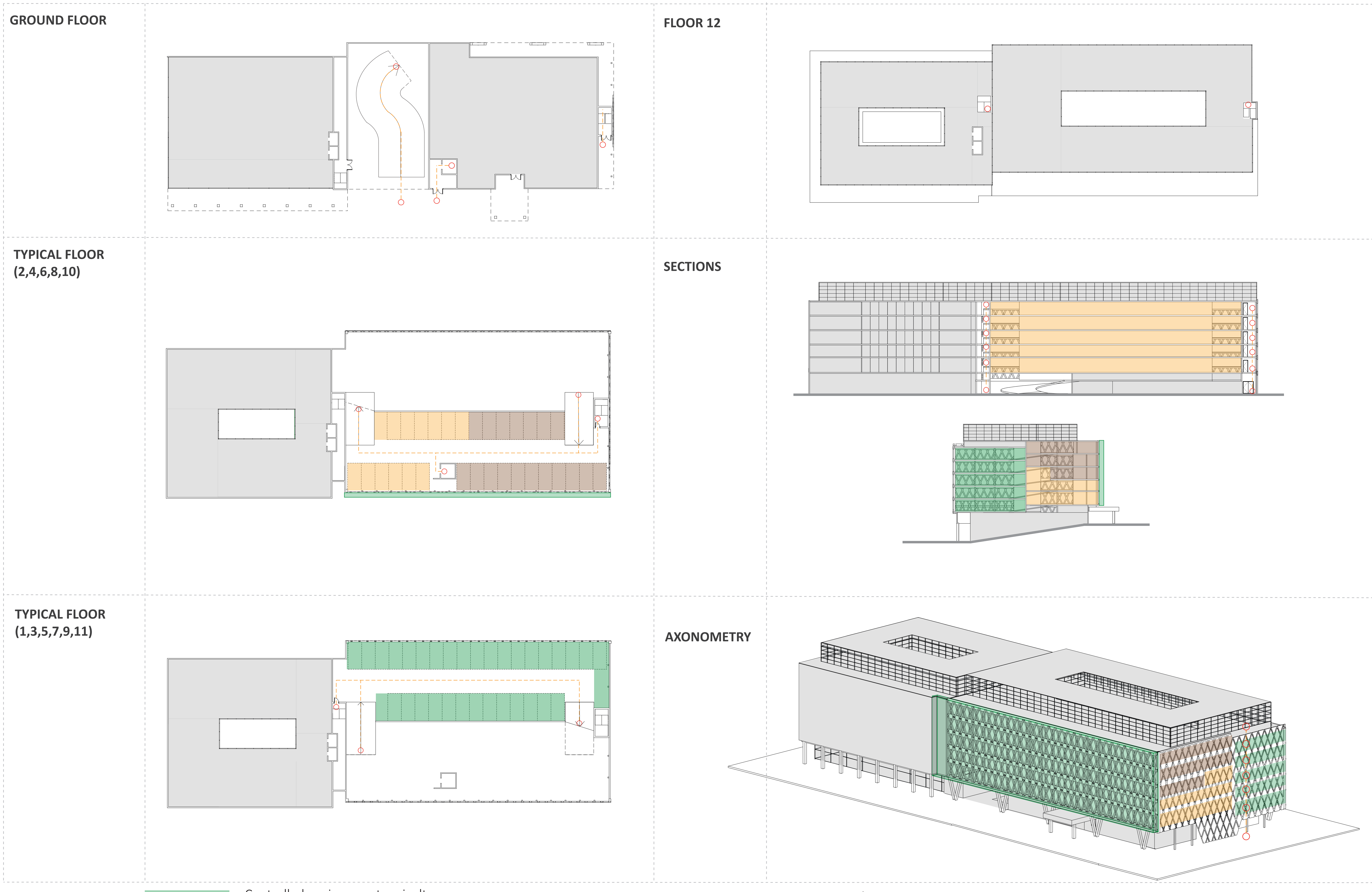
0 8 16 24 32 40

Figure 52: Architectural analysis of the limitations for the adaptive reuse of Prince Street Car Park for CEA, architectural phase of the guide application, step 1

The architectural analysis of Prince Street Car Park revealed that the structural conditions of the concrete slabs, the structural wall located in the central axis of the garage, the walls supporting internal staircases, and the columns attached to the external cladding elements should be assessed. Such an analysis is beyond the scope of this thesis, as a structural engineer should conduct this before specific design decisions are made. Exploring the limitations caused by the requirement to enclose the car parking structure revealed that creating a controlled environment entails the application of cladding materials on the east, west and north elevations. Depending on the orientation, some façades can be developed as FFs. When investigating the structural elements, it becomes clear that the floor-to-floor height varies significantly between different storeys. The distance between the 4^{th} and 6^{th} floors is too low (2.40 m) to implement the required uses, thus in this area concrete slabs need to be partially taken out to have double-height spaces. Another architectural element which limits this potential on floors 2, 4, 6, 8 and 10 is the lift located in the centre of the layouts. The exploration of the existing circulation within the garage shows that vehicular access to the levels analysed is available through internal ramps, while pedestrian access is via two staircases and one lift in the eastern section of the building. For transporting goods and people (staff, visitors), one additional lift should be implemented in the western part of the garage. As the architectural elements providing access to the car park and the circulation within it are included in evacuation routes, the specific requirements have to be analysed in the further design stages (beyond the boundary of this thesis) to decide if any alterations to the horizontal or vertical circulation should be introduced for fire safety.

Step 2: The architectural exploration of the various scenarios for the adaptive reuse of Prince Street Car Park for CEA and associated facilities

In this step of the guide, data collected in the first step of the architectural phase is evaluated in the context of the data gathered through the literature review (Chapter 4) on the parameters and elements that affect the selection of the type and location of productive space within and upon Prince Street Car Park. This leads to the identification of the architectural approach that will develop the viable scenario for up-cycling the garage for CEA and associated facilities which is presented in Figure 53.



Controlled environment agriculture
Uses supplemental to controlled environment agriculture
Social uses
Main circulation routs

0 8 16 24 32 40

Figure 53: Initial design scenario for the adaptive reuse of Prince Street Car Park for CEA, architectural phase of the guide application, step 2

The results of the planning phase of the guide indicates that Prince Street Car Park should be repurposed as a mixed-use building, for instance as an innovative business incubator clustered around local food production and supply. The multi-storey garage should include a market place and market-related facilities required in the inner-city of Bristol. As Prince Street Car Park is adjacent to the Bristol Hotel, a functional connection between the CEA operation and the hotel should be developed as a strategy to offer new facilities for urban residents and tourists, for instance retail, leisure, entertainment, and cultural space as a background for the CEA operation. The ground floor uses should reinforce the connection to the dockside, and introduce new leisure opportunities attractive for pedestrians and cyclists as a contribution to community engagement within the CEA operation, and new job creation. The facilities arising from the application of the planning phase of the guide include a school and workshop area, guided tours within the building-integrated CEA practice, as well as a cultural and art space (e.g. restaurant, gallery or exhibition space). The architectural analysis of Prince Street Car Park revealed that the ground floor and the roof are occupied by the hotel's facilities, which should be retained. This leads to the conclusion that the investigation should focus on levels 1 to 11, and the elevations of the structure.

The architectural exploration shows that levels 1, 3, 5, 7 and 9 should be repurposed for CEA installations. This location would benefit from the western orientation of the longer façade, which maximises the transmission of solar radiation to the internal space. Placing hydroponic facilities along this façade would contribute to productivity and reduce energy use for artificial lighting. Thus, a CEA operation could be developed within this part of the multi-storey garage as a PFSL, considered the most viable design scenario owing to lower energy use for lighting (Çakir & Şahin, 2015; Kozai, Niu, & Takagaki, 2015; Nadal, Alamús, et al., 2017) and the increased productivity of an agricultural system lit by sunlight (Jenkins, 2018). However, the installation of permeable materials to create a controlled environment for plant growth increases the initial financial investment, which, especially in the case of temporary up-cycling for CEA, may be too high. Therefore, a second approach would be to use shipping containers and multiply them vertically and horizontally within the levels analysed, thus developing a PFAL without the need for enclosing the garage. Finally, the structure could be enclosed with solid materials, and a PFAL developed. Hydroponic units should be designed using the module designated by the parking bays, which allows for transporting them to another location. Depending on the type of CEA selected, to control the internal environment parameters for plant cultivation, glass cladding, ETFE foil or a solid material should be used for enclosing the internal area of the garage. As the west façade is structured from the concrete X components unique to Prince Street Car Park, various options for the installation of the cladding should be considered, for instance fitting the glass to the interior of the garage, which enables retaining and exhibiting the particular concrete components.

Improving the aesthetics of the interior of the garage should be done through modernisation. Vehicular access to the levels analysed is available through internal ramps, while pedestrian access is via one staircase. For transporting goods and people (staff, visitors) one additional lift should be implemented in this section of the garage.

Levels 2, 4, 6, 8 and 10 are recognised as the floors with the highest potential for locating the innovative business incubator, market and market-related facilities, as well as uses which contribute to community engagement within the CEA operation, including schools, workshops and a cultural space (e.g. restaurant, gallery or exhibition space). As the investigation into the floor-to-floor height of the multi-storey garage revealed, the distances between the 4th and 6th floors are too low (2.40 m) to implement the required uses. Thus, in this area, concrete slabs need to be partially taken out to have double-height spaces and voids. The levels analysed are accessible through one internal staircase attached to the northern elevation, and one lift located in the central area of the layouts. All actions taken for repurposing Prince Street Car Park should focus on the improvement of the aesthetics of the interior of the garage through modernising and greening the building.

The architectural exploration of the outer part of Prince Street Car Park revealed the opportunity to develop FFs on the eastern and western façades. Due to the location of uses arising from the evaluation of findings from the first step of the planning phase of the guide, an FF should be implemented on the eastern façade along the section of the building where social facilities are proposed. This location would benefit the internal microclimate of the part of the building used for the innovative business incubator, marketplace, school, workshops, restaurant and cultural events, as well as bringing related energy savings. Another opportunity derived from the development of an FF on the eastern façade is the strong visibility of CEA units in the central district of Bristol. The location of an FF on the western elevation would reduce sunlight transmission to the hydroponic installations on levels 1, 3, 5, 7 and 9. Thus, implementing an FF from the west is possible, but not recommended due to the risk of an increased financial cost for energy required to light the CEA operation. The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities for implementing CEA in the internal and external areas of Prince Street Car Park is shown in Tables 24 and 25.

Table 24: The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the internal area of Prince Street Car Park

	Area [m^2]					
Level	CEA	Uses supplemental to CEA	Social uses	Circulation	Existing use	Total area
0	0	0	0	486.2	1445.8	1932
1	442	0	0	293.3	816	1551.3
2	0	231.8	165.2	297.7	0	694.7
3	442	0	0	293.3	816	1551.3
4	0	231.8	165.2	297.7	0	694.7
5	442	0	0	293.3	816	1551.3
6	0	231.8	165.2	297.7	0	694.7
7	442	0	0	293.3	816	1551.3
8	0	231.8	165.2	297.7	0	694.7
9	442	0	0	293.3	816	1551.3
10	0	231.8	165.2	297.7	0	694.7
11	442	0	0	293.3	816	1551.3
12	0	0	0	14.5	1798.6	1813.1
Total	2652	1159	826	3749	8140.4	16526.4
%	16.00%	7.00%	5.00%	22.70%	49.30%	100%

Table 25: The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the external area of Prince Street Car Park as FFs

	Vertical area [m^2]	
Elevation	FF	Total area
N	0	495.6
E	700	1377.6
W	0	1377.6
S	0	462
Total	700	3712.8
%	18.90%	100%

7.3.3. Application of the environmental phase of the guide

Criterion: The architecture of the modern movement car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of CEA operation

Step 1: The identification of the environmental opportunities and limitations for the adaptive reuse of Prince Street Car Park for CEA

In this step of the environmental phase of the guide, data from the planning phase is used as the basis for the investigation into opportunities and limitations for implementing resource-efficient technologies and alternative energy technology options in the process of up-cycling the multi-storey garage for a CEA operation. The results of the planning phase of the guide revealed that the crucial environmental drivers and motivations for repurposing Prince Street Car Park for UF are clustered around the aim to reduce the adverse environmental impact of the current food supply system and urban development. While the planning phase of the guide focuses on the urban scale of the proposed adaptive reuse, the environmental phase of the guide explores the architectural scale of the concept. The specific drivers and motivations identified in the planning phase include improved water use efficiency, improved building energy efficiency, sustainable architecture, energy-efficient productive architecture and enhanced closed cycles. In this step of the environmental phase these drivers and motivations are linked to the environmental opportunities and limitations defined in Chapter 5.

The first opportunity identified is to implement resource-efficient technologies and alternative energy technology options in the process of the adaptive reuse of the Prince Street Car Park for CEA operation. This should be done through the optimal management of the indoor microclimate, installing energy-efficient lighting (LED lighting) and a lighting control system, regenerating alternative freshwater sources, rainwater harvesting, solar power systems (e.g. PV panels), wind power systems (e.g. Wind Assured system), ground sourced heat pumps, using biomass and developing a closed-loop plant cultivation system. The second opportunity identified is to create technical synergies between the CEA operation and other uses located within Prince Street Car Park and the adjacent hotel. Such a symbiotic relationship may enable exchanging energy, water, heat, and reusing CO_2 and O_2, which contributes to improved water use efficiency, improved building energy efficiency and enhanced closed cycles. Applying these technologies would allow for retrofitting the modern movement garage as an energy-efficient productive and sustainable architecture, which minimises the adverse environmental impact of CEA associated with excessive resource use.

The application of the opportunities identified may be limited by a lack of compatibility between innovative technologies and the existing infrastructure in Prince Street Car Park. Another constraint may arise from the fact that the innovative technologies required for creating synergies between CEA installations and new uses are in the early stages of development, and many of them require further technical amendments to work effectively. The high initial costs of the implementation of resource and energy-efficient technologies, alternative energy technology options and technological synergies are recognised as an economic limitation which may significantly reduce the installation of technologies aimed at minimising the demand of the CEA operation for resources. These constraints may create a barrier for repurposing Prince Street Car Park as an energy-efficient productive and sustainable architecture.

Step 2: The analysis of opportunities for applying resource-efficient technologies and alternative energy technology options in the process of up-cycling Prince Street Car Park for CEA

The design scenario for repurposing Prince Street Car Park for a CEA operation developed in the architectural phase of the guide is the foundation for exploring the opportunities for applying resource-efficient technologies and alternative energy technology options in this step of the environmental phase of the guide.

First, for water-saving and recycling and closed-loop plant cultivation, a system should be developed in the PFSL occupying the designated internal areas of the garage and the FFs. Regenerating alternative freshwater sources should be applied within all types of CEA operation. Rainwater harvesting installations should be located on the rooftop of the multi-storey garage. Second, for energy savings, energy-efficient electric devices should be used within the CEA operation, for instance energy-efficient pumps and boilers, solid-oxide fuel cells and an LED lighting system. The indoor microclimate within the PFSL and the FF proposed in the architectural phase of the analysis should be managed in a way that provides optimal environmental parameters for plant growth. While Prince Street Car Park is functionally and spatially connected to the hotel, technical synergies should be developed between the CEA operation, other uses allocated during up-cycling the structure and the existing hotel. Such synergies should provide heat exchange and reuse of CO_2 and O_2. A further opportunity is associated with the FF located on the eastern façade, which should be developed to optimise thermal comfort within the structure. Third, alternative energy technology options should be installed within the garage to reduce the reliance of CEA installations on urban resources. While the south elevation, considered optimal for locating PV for productivity (Lee, Park, Jung, & Park, 2017; Roberts & Guariento, 2009), is not available for installations due to the link to the hotel, non-optimal orientations to be considered include the eastern and western façades. In these locations, BIPV should be integrated on the west façade, with glass or ETFE foil installed as the external cladding, and on the east elevation with the double-glazed façade accommodating an FF. The building's self-sufficiency should be improved by installing BIWT, for instance the system developed by Park et al. (2015) or the Wind Assured system indicated by one of the experts interviewed (Chapter 5). Further alternative energy technology options which should be considered include industrial heat exchange between the CEA operation and other uses located within Prince Street Car Park or neighbouring buildings, geothermal energy and biomass use. The specific site analysis, technical details and spatial opportunities for implementing these technologies should be considered after the architectural project is proposed in the next stage of research, beyond the boundaries of this thesis.

7.4. Case study 3: Brighton & Hove, London Road Car Park (Fig. 54)

Figure 54: London Road Car Park, Brighton & Hove, UK, Multifamily building on the rooftop of the car parking structure. Photo: Szopinska-Mularz 2019

7.4.1. Application of the planning phase of the guide

Criterion: The local authority must allow the up-cycling of inner-city modern movement car parking structures and accept CEA as a future use

Step 1: The analysis of the planning documentation concerning the selected inner-city area and the identification of the planning opportunities and limitations for repurposing London Road Car Park for CEA.

The location of London Road Car Park in the urban context is presented in Figure 55. The strategic planning documents selected for the analysis include the London Road Central Masterplan (Brighton & Hove City Council, 2009), the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) and the Brighton & Hove Local Plan (Brighton & Hove City Council, 2005).

Figure 55: Location of London Road Car Park in the urban context. Retrieved and adapted from https://digimap.edina.ac.uk, created 26 March 2018

The key objectives for the development of Brighton & Hove defined in the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) is the achievement of the following:

1) *A strong and prosperous city,*

2) *A sustainable city,*
3) *An attractive city,*
4) *Healthy and balanced communities* (Brighton & Hove City Council, 2016, p. 18)

These objectives are used as the foundation for exploring the potential opportunities and limitations for repurposing London Road Car Park for CEA in the first step of the planning phase of the guide. Other planning documents listed above provide supplementary data relevant for the development of the inner-city of Brighton & Hove for this analysis.

The opportunities and limitations listed in the first step of the planning phase of the guide can be identified in all four of the objectives defined in the Brighton & Hove City Plan (Brighton & Hove City Council, 2016). Within the first objective, new development is expected to support urban regeneration. As the Brighton & Hove Local Plan (Brighton & Hove City Council, 2005) highlighted:

*Regional planning guidance, (RPG 9) proposes that 60% of all development should be located on previously built-on land (brownfield sites). The strong environmental constraints that make Brighton & Hove such an attractive place to live, mean that most employment land will have to be found by recycling existing industrial and other redundant sites ((*Brighton & Hove City Council, 2005, *p. 70).*

Up-cycling London Road Car Park may contribute to this goal in the future, when the garage becomes redundant, by adapting the modern movement architecture for an alternative use. This would reconcile the continuity of the urban fabric with the need for contemporary design solutions in the inner-city area. Repurposing the building for CEA would reduce the initial investment for this type of UF, due to lower initial financial investment. Thus, the planning proposal for the adaptive reuse of London Road Car Park should highlight the opportunity to improve the economic performance of the CEA business when implemented within an existing structure. This fact applies to point four of the opportunities listed in the first step of the planning phase of the guide.

The first objective focuses on sustainable business growth and innovation in Brighton & Hove. Building a viable business strategy and ensuring the long-term economic performance of the CEA practice would contribute to this goal. The results of the interviews conducted for this thesis offered recommendations for developing the environmental and economic viability of building-integrated UA. First, the proposed up-cycling should be supported by resource-saving technologies and alternative energy production methods. These installations would minimise the reliance of CEA on urban resources, and reduce the operational costs associated with the control of the internal environment for plant growth. A further contribution may be made by developing technical synergies with neighbouring buildings. As there are three multifamily buildings located on the roof of London Road Car Park, the potential synergies between the CEA operation and the residential function could include water and energy exchange. Second, the business performance of the CEA operation would be higher if it adopted circular economy principles, involving collaborative marketing with farmers from the region and extending revenue opportunities by introducing activities focused on CEA for the community and tourists (e.g. schools, workshops, event space, guided tours, restaurant or café). While the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) highlights the role of mixed-use development in the area, implementing CEA together with additional facilities supportive of UA and increasing community infrastructure would enhance the economic performance of the CEA operation and the social cohesion of the area. Implementing a CEA operation would require skills training and education around technical food systems, and would generate new jobs, thus further contributing to the economic goals of the city. Another opportunity is to develop local distribution channels to supply grocery stores within Brighton & Hove (Fig. 56). Finally, the development of CEA in the inner-city would offer a space for innovation and research into sustainable business growth. Specific disciplines may involve the topic areas identified by the experts in the interviews (Chapter 5), for instance resource use efficiency, nature-based solutions in urban areas, innovative food production techniques, circular economy or the food-water-energy nexus. These improvements correspond with the fourth and fifth points of the opportunities listed in the first step of the planning phase of the guide.

Within the second objective, repurposing London Road Car Park for CEA would contribute to the sustainability of Brighton & Hove by up-cycling the existing building with an alternative use instead of demolishing it and replacing it with new investment. The environmental sustainability framework developed within the current planning documentation supports the efficient use of previously developed land (Brighton & Hove City Council, 2009, 2016). For instance, the London Road Central Masterplan highlights:

As part of an approach to minimise resource impacts, sustainable retrofitting and refurbishment of existing development should be fully explored before adopting a 'demolish and rebuild' approach in the masterplan area (Brighton & Hove City Council, 2009, p. 34).

Up-cycling the multi-storey garage would preserve the embodied energy within the structure, prevent the generation of demolition energy, and reduce material waste. The implementation of sustainable technologies for energy generation and savings would reduce the reliance of CEA on urban resources, and contribute to a reduction in the ecological footprint of Brighton & Hove. Furthermore, local food production and distribution enhanced by CEA in the inner-city would lower the pressure on agricultural land and reduce the food miles travelled by products cultivated within the global food chain and imported into the city. These benefits apply to the fifth point of opportunities listed in the first step of the planning phase of the guide.

Figure 56: The distances between London Road Car Park and large, medium and small grocery businesses located in the area. *Retrieved and adapted from https://digimap.edina.ac.uk, created 26 March 2018*

The third objective formulated in the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) is to increase the attractiveness of the urban area. To achieve this goal, the planning document (Brighton & Hove City Council, 2016) indicates the importance of design excellence, which responds positively to the individual character of the specific neighbourhood and allows for enhancing and maintaining its distinctive style and varied heritage. Regarding the city's vacant buildings of local or national architectural interest, the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) highlights the requirement to bring them back into appropriate use. The modern movement architecture of London Road Car Park could be retained when the proper use is found. The interviews with experts (Chapter 5) revealed that CEA might be one of the facilities which does not trigger substantial changes or require high financial investment within the structure of a building designed for cars. Thus, retrofitting London Road Car Park for CEA may become a strategy for up-cycling the structure instead of demolishing it and replacing it with a new build. This would enhance the continuity of the urban fabric in the inner-city area and preserve its distinctive character. Repurposing London Road Car Park would offer an opportunity to improve the aesthetics of the garage, for instance by greening the external skin by implementing FFs and modernising the structure. While the crucial recommendation of the London Road Central Masterplan (Brighton & Hove City Council, 2009) for Providence Place is to provide active frontages to encourage users to stay longer, this long-term improvement should be developed when up-cycling London Road Car Park. The planning document (Brighton & Hove City Council, 2009) does not specify uses to be implemented within the London Road district, but highlights the indicative role of the land use recommendations, which include an increase in community infrastructure and office floorspace. These improvements contribute to point six of the opportunities listed in the first step of the planning phase of the guide.

The fourth objective focuses on healthy and balanced communities in Brighton & Hove. UA in the inner-city would increase the visibility of local food production and improve its transparency. Engaging the community in CEA, for instance by offering educational opportunities around healthy eating habits or the nutritional quality of food, would improve the consumer awareness, which may bring about nutrition-related health outcomes over a long-term perspective. This corresponds with point two of the opportunities defined in the first step of the planning phase of the guide. The social cohesion of the inner-city may benefit from the adaptive reuse of London Road Car Park for CEA if the operation offers educational opportunities for urban residents, space for social events and a community food growing area. These facilities may enhance the local community, reduce inequalities related to food and improve the quality of living in the inner-city area. Another benefit for residents' health would be brought about by the installation of sustainable technologies within London Road Car Park, which reduce the reliance of the development on urban resources and lowers its adverse environmental impacts. This would contribute to air quality improvement, defined as one of the goals with the fourth objective. The improvements presented would benefit the first opportunity determined in the first step of the planning phase of the guide.

When analysing the planning limitations for the adaptive reuse of London Road Car Park for CEA, the first constraint arises from the fact that, although planning documentation supports UA (Brighton & Hove City Council, 2016), food growing is expected to be incorporated within new development and green infrastructure, as a facility which brings benefits to the community. UA is perceived as an opportunity to improve community cohesion and offer new activities for urban residents rather than enhancing local food supply within the city. Building-based CEA is not mentioned in the planning documents explored. The Brighton & Hove City Plan (Brighton & Hove City Council, 2016) highlights the temporary approach to UA:

On-site food growing initiatives (…) will be required and should be designed to provide flexibility in use to reflect changes in trends (Brighton & Hove City Council, 2016, p. 204)

This statement expresses uncertainty concerning the continuity of community interest in UA. It indicates the possibility for implementing alternative uses in line with new trends with higher social values or higher revenue. Thus, when locating UF in Brighton & Hove, this is not designated as a permanent site allocation. This constraint corresponds with the first and third points of the planning limitations listed in the guide.

As indicated in the interviews with the experts, the main reason for this constraint may be a lack of expertise in building-based CEA, which lowers the acceptance of this type of UF and offers priority to in-soil community UA. The lack of knowledge may trigger uncertainties and misunderstandings, for instance difficulties in assessing the social, economic and environmental performance of a CEA operation located in an inner-city multi-storey garage, or assumptions about potential environmental issues (e.g. noise, air or light pollution). These aspects, distilled from the interviews (Chapter 5), could become a significant limitation due to the priorities within the second objective defined by the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) as well as the principles formulated in the London Road Central Masterplan (Brighton & Hove City Council, 2009) aimed at the reduction in the ecological footprint of the city associated with the use of energy, water, resources and transport. Such constraints correspond with point 2 of the limitations from the planning phase of the guide.

Further challenges for repurposing London Road Car Park for CEA relate to the economic viability of the UF operation. While the first objective indicated in the Brighton & Hove City Plan (Brighton & Hove City Council, 2016) highlights the role of the continued enhancement of the economic performance of the city, the financial viability of a building-based CEA practice may be questioned. The crucial issues arise around the high initial and operating costs of CEA, which include financial investment in hydroponic installations and alternative energy technology options, enclosing the space for CEA and controlling the internal environmental parameters, as well as the high demand for resources raising the costs of food production. Point five of the planning limitations listed in the guide is linked to these issues.

Step 2: The determination of the drivers and motivations for the adaptive reuse of London Road Car Park for CEA arising from the analysis of the planning documentation

In this step of the guide, the data gathered in the previous step is linked to the key drivers and motivations for the implementation of UA formulated in the literature review (Chapter 4). These categories are: (1) Improved social cohesion, (2) Improved health of urban residents, (3) Space for innovation and research, (4) Long-term economic viability of the CEA project, (5) Reduced adverse environmental impact of the current food supply system and urban development and (6) Improved aesthetics of a car parking structure. The results of step 2 are presented in Table 26.

Table 26: The determination of the potential drivers and motivations for the adaptive reuse of London Road Car Park for CEA as a contribution to the objectives defined for Brighton & Hove in the planning documentation, planning phase of the guide's application, step 2

	Opportunities (interviews with experts)	**Objectives for the city defined in the planning documentation** (first step of the planning phase of the guide)	**Contribution of the adaptive reuse of the car parking structure for CEA to the identified priorities** (first step of the planning phase of the guide)	**Drivers and motivations** (literature review)
1	Improved social cohesion: - education, - job development, - community food growing, - space for social events	- healthy and balanced community	- up-cycling the multi-storey garage as a mixed-use development focused on enhancing community infrastructure (e.g. school, workshop, restaurant, gallery, exhibition space, community food growing area), - providing educational opportunities and guided tours focused on CEA, - installing sustainable technologies for air quality improvement	- educational opportunities, - community building (empowerment fun), - spaces for experiment and creativity, - improved public awareness, - improved living quality
2	Improved health of urban residents: - improved access to nutritious food, - education on a healthy diet	- healthy and balanced community	- placing food production in the inner-city of Brighton & Hove, - offering educational programmes and workshops on a healthy diet, - offering guided tours to the public	- improved transparency of food production, - connection between consumers and food production, - improved consumer awareness, - nutrition-related health outcomes, - cross-sectoral effects on poverty and health care costs,

				- improved urban self-sufficiency
3	Space for innovations and research into: - resource use efficiency, - nature-based solutions in urban areas, - innovative food production techniques, - circular economy, - food-water-energy nexus	- a strong and prosperous city	- developing CEA as a sustainable and innovative business, - up-cycling the multi-storey garage as a mixed-use building focused on sustainability and innovation in UA (e.g. resource use efficiency, nature-based solutions in urban areas, innovative food production techniques, circular economy, food-water-energy nexus)	- new business models, income and employment, - improved regional value chains, - innovation for attracting investors and showcasing, - local economic development, - new inter-divisional, inter-governmental and/or cross-sectoral collaborations
4	Long-term economic viability of the CEA project: - adapted circular economy principles, - extended revenue opportunities, - involvement in collaborative marketing, - development of local distribution channels	- a strong and prosperous city	- adapting the modern movement architecture for alternative use, - reducing operational costs by developing CEA as a sustainable business, which relies on resource-saving technologies and alternative energy production methods, - reducing the initial financial investment associated with the construction of a new building for CEA, - adapting circular economy principles, - extending revenue opportunities by implementing a mix of uses supportive for CEA operation and available for the community and tourists (e.g. school, workshops, event space, guided tours, restaurant or café), - involvement in collaborative marketing with farmers from the region,	- reduction in costs related to conventional agriculture, - local economic development, - potential products and high yields, - new business models, income and employment, - new marketing opportunities, - improved regional value chains, - new inter-divisional and/or cross-sectional collaborations

			- developing local distribution channels in Brighton & Hove, - generating new jobs, skills training and education on CEA	
5	Reduced adverse environmental impact of the current food supply system and urban development: - reduced food miles, - lower pressure on agricultural land, - passive technologies, - synergies between CEA operation and other uses	- a strong and prosperous city, - a sustainable city	- reducing the adverse environmental impact of the development by implementing resource-efficient technologies and renewable energy production methods, - developing technical synergies between the residential buildings located on the rooftop of the garage and the CEA operation (e.g. water and energy exchange), - preventing embodied energy loss and demolition energy generation, reducing material waste, - lowering the pressure on agricultural land, - reducing food miles required to supply foods produced within the global food system to Brighton & Hove	- reduced emissions and transport, - improved water use efficiency, - improved building energy efficiency, - improved urban self-sufficiency, - reduced pressure on agricultural land, - sustainable architecture, - energy-efficient productive architecture, - enhanced closed cycles, - experience in a greenhouse and climatic architecture
6	Improved aesthetics of a car parking structure: - greening the building, - modernisation	- an attractive city	- preserving the modern movement architecture, - greening the external skin of the building (e.g. by implementing FFs and RTGs), - modernising the car parking structure, - implementing active frontages to encourage longer user stay (e.g. community infrastructure, offices)	- improved building aesthetics, - adaptive reuse of derelict buildings

7.4.2. Application of the architectural phase of the guide

Criterion: The architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities

Step 1: The identification of the architectural opportunities and limitations for the adaptive reuse of London Road Car Park for CEA

The first step of this phase of the guide focuses on the architectural analysis of London Road Car Park and the critical evaluation of the findings, from the perspective of an architect, for the further development of the concept leading to repurposing this multi-storey garage for a mixture of uses gathered around a CEA operation. The architectural analysis of London Road Car Park investigates the topic areas arising from the interviews presented in Chapter 5.

The analysis which follows in Figures 57 and 58 was conducted to address the architectural opportunities defined in the guide.

Figure 57: Architectural analysis of the opportunities for the adaptive reuse of London Road Car Park for CEA, architectural phase of the guide application, step 1

Figure 58: Architectural analysis of the opportunities for the adaptive reuse of London Road Car Park for CEA, architectural phase of the guide application, step 1

0 8 16 24 32 40

The flexibility of layouts of London Road Car Park is associated with the opportunity for the functional arrangement of space for CEA, including internal space for a PFAL and a PFSL, as well as external space for an RTG and FFs. The architectural analysis shows that all of the storeys of London Road Car Park are repeated, and sectioned by a regular grid of columns. There are four internal staircases which spatially divide the layouts. The characteristic features of this multi-storey garage include the south-eastern section of the building which was developed as a ramp with allocated parking bays, and the south-west elevation which was created by an atrium. This atrium extends from the ground level of Providence Place to the street level at New England Street. The constraints for the flexibility of the ground floor are the two enclosed spaces for staff and maintenance. The existing walls and functions, still relevant after up-cycling the structure for CEA, limit the flexible implementation of hydroponic units on that level. The rooftop of the garage is occupied by three multifamily buildings (Mayflower Square) and two sports fields. As highlighted by the experts in the interviews (Chapter 5), these uses should be retained. Thus, the rooftop area is excluded from the investigation into the architectural potential of London Road Car Park for CEA. When evaluating this data, it becomes clear that CEA units can be designed for the interior of the multi-storey garage and multiplied vertically as VF. The atrium attached to the south-west elevation of the structure is unoccupied and naturally lit. This area offers flexible potential for the placement of CEA operations. Another opportunity arising from the building's flexibility can be recognised on the elevations of the car park, of which three - the north-east, the north-west and the south-east - could become subjects for further analysis, for locating FFs in the second step of the architectural phase of the guide.

The architectural investigation revealed the modularity of layouts of London Road Car Park. First, two basic modules are created by the sections of the garage - the south-western and the south-eastern. The second module is developed by a regular grid of columns, which vertically link all three levels of the garage. Third, the layout of parking bays, adjusted to the grid of columns, determines the basic module for the spatial arrangement of the multi-storey garage with CEA units. The modules outlined allow for multiplying the hydroponic growing units horizontally and vertically, which leads to the development of VF.

The accessibility of the multi-storey garage is associated with vehicular access provided by ramps, and pedestrian access through staircases and lifts. Vehicular access to London Road Car Park is supplied on the ground floor from Providence Place. The circulation of cars is continuous inside the garage through the internal ramps, and ends at the departure gate located on the second floor leading to New Road. Pedestrian access to all levels is provided by three internal staircases, the first in the north corner of the structure, the second attached to the north-eastern façade and the third inside the layout of the garage, between the main vehicular movement area and parking bays. The north-eastern and south-western sections are connected by one additional staircase. There is one lift providing access to all levels. The architectural analysis of London Road Car Park revealed that the existing ramps and staircases would provide efficient circulation for the needs of a CEA operation.

The accessibility of London Road Car Park is linked to the security of the garage. Repurposing the structure as a mixed-use development requires securing the building to prevent unauthorised access. The architectural analysis shows that the vehicular entrance and departure gates should be enclosed, and give access to authorised vehicles for the circulation of agricultural products only. Access through the two internal staircases - the first in the north corner of the structure, the second attached to the north-eastern façade - should be controlled at the ground floor level, as they serve as the primary pedestrian access to the multi-storey garage. As the areas designated for social uses may be open during working hours, the CEA area should be secured at all times to prevent theft, damage and the spread of disease.

The architectural analysis of the aesthetics of London Road Car Park revealed the requirement to amend the visual perception of the interior and the south-eastern elevation of the concrete structure. The modernisation of the internal space should be linked to its location and the needs of specific facilities, and include all levels currently used as a garage. It is necessary to improve the aesthetics of the atrium, which was developed for the transmission of sunlight to the interior of the garage. As the north-eastern and north-western elevations are enclosed with concrete vertical elements, unique to London Road Car Park, the architectural approach taken to aesthetically amend these external areas should focus on retaining these components as relics of modern movement architecture in the inner-city of Brighton & Hove. The south-eastern elevation requires aesthetic improvement, for instance by greening the building through an FF.

The analysis which follows in Figures 59 and 60 was conducted to address the architectural limitations.

Figure 59: Architectural analysis of the limitations for the adaptive reuse of London Road Car Park for CEA, architectural phase of the guide application, step 1

0 8 16 24 32 40

Figure 60: Architectural analysis of the limitations for the adaptive reuse of London Road Car Park for CEA, , architectural phase of the guide application, step 1

0 8 16 24 32 40

The architectural analysis revealed that the structural elements which need to be investigated by the structural engineer include the concrete slabs, columns and ramps developed for the south-eastern section of the building. Such an analysis is beyond the scope of this thesis, as a structural engineer should conduct this before the specific architectural design is proposed. To address the limitations caused by the requirement to enclose the structure to create a controlled environment, external cladding should be implemented on the north-eastern and north-western elevations, and partially on the south-eastern elevation. Depending on the orientation, some façades can be developed as FFs. The investigation into the structural elements shows that the floor-to-floor height is efficient for accommodating CEA and new uses. When exploring the existing circulation, it becomes clear that it is suitable for the needs of the new facilities. Vehicular access is available through the north-eastern façade. The circulation is continuous inside the structure, through the internal ramps, and ends at the departure gate located on the second floor leading to New Road. Pedestrian access to all levels is provided by three internal staircases, the first in the north corner of the car park, the second attached to the north-eastern façade and the third inside the layout of the garage, between the main vehicular movement area and parking bays. The north-eastern and the south-western sections of the structure are connected by one additional staircase. There is one lift providing access to all levels. As the architectural elements developed for accessing the multi-storey garage and circulating around it are included as evacuation routes, specific requirements will have to be analysed in the further design stage (beyond the boundary of this thesis) to decide if any additional staircases should be built for fire safety.

Step 2: The architectural exploration of the various scenarios for the adaptive reuse of London Road Car Park for CEA and associated facilities

In this step of the guide, data collected in the first step of the architectural phase is evaluated in the context of the data gathered in the literature review (Chapter 4) on the parameters and elements that affect the selection of the type and location of productive space within and upon London Road Car Park. This leads to the identification of the architectural approach that develops a viable architectural scenario for the design of a CEA operation and associated facilities within the car parking structure analysed, presented in Figure 61.

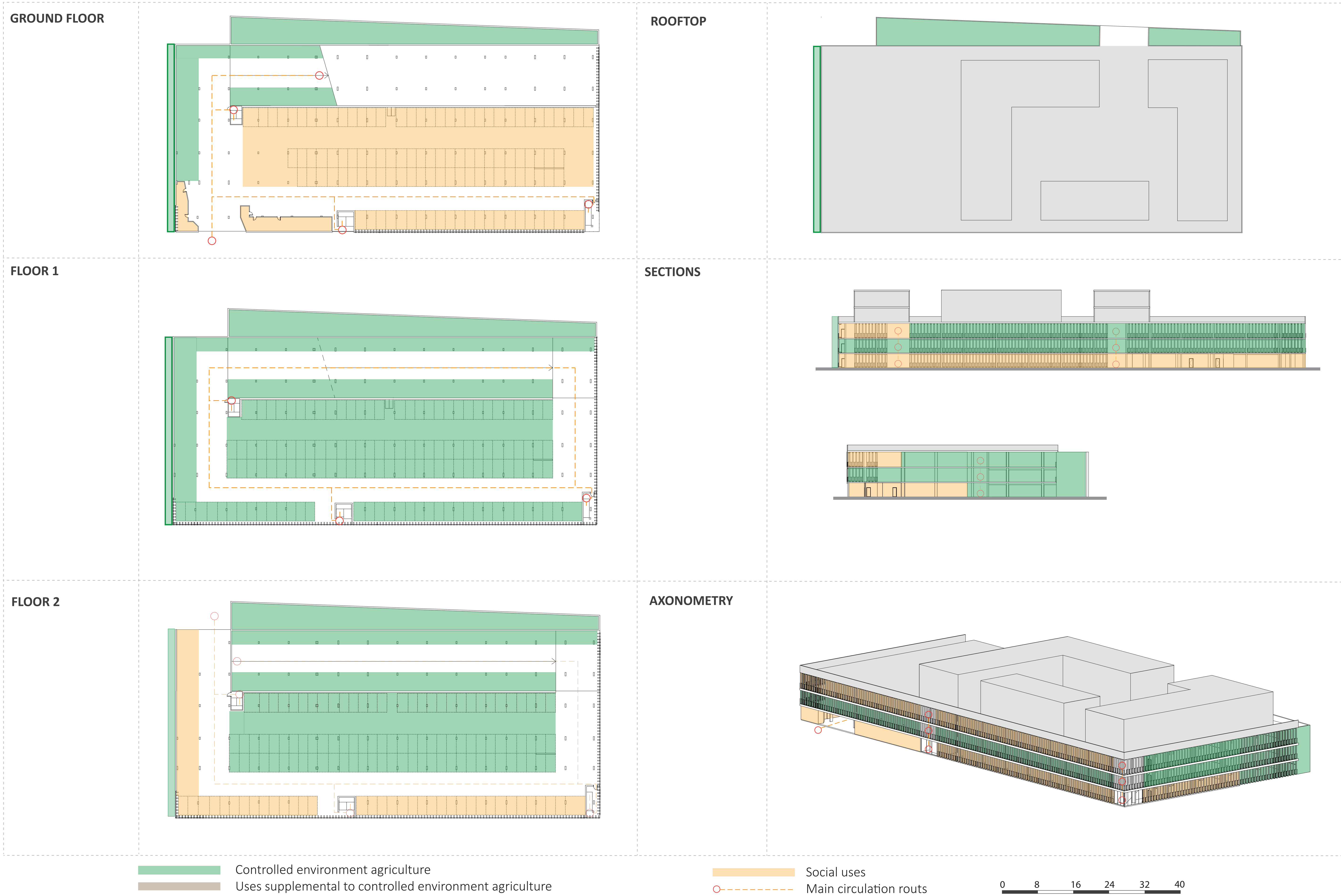


Figure 61: Initial design scenario for the adaptive reuse of London Road Car Park for CEA, architectural phase of the guide application, step 2

The architectural analysis of London Road Car Park shows that the adaptive reuse process may include the internal area of the multi-storey garage, and the three elevations. The rooftop is occupied by three multifamily buildings and a sports field. These uses should be retained, and therefore the rooftop area is excluded from the investigation.

The planning phase of the guide provided data on the uses relevant for up-cycling London Road Car Park. The garage should be repurposed as a mixed-use development, with CEA as the primary function with community infrastructure gathered around the UF operation. The facilities which should be implemented together with the CEA installations include schools, workshops, a restaurant, gallery, exhibition space and community food growing area. To expand the opportunities for users staying longer in the district, as indicated in the London Road Central Masterplan (Brighton & Hove City Council, 2009), the north-eastern ground floor area should accommodate social facilities, for instance, workshops, a restaurant and exhibition space. This location allows for introducing new active frontages on the north-eastern façade, which would contribute to the improvement of the user experience and perception of Providence Place. The ground floor area is accessible for pedestrians through two existing entrances located in the north corner of the building and the north-eastern façade. The architectural analysis revealed that the north-eastern section of the second floor should be used for developing community infrastructure gathered around UF, for instance the residents of the Mayflower Square situated on the rooftop of London Road Car Park. This is because the second floor is located at the level of New England Street, which provides a direct link between the interior of the garage and the neighbourhood. The second floor can also be accessed from the ground floor through two existing staircases located in the north corner of the building and the north-eastern façade, as well as one internal staircase.

An opportunity for implementing a CEA operation has been identified in the south-western area of London Road Car Park, which was developed as a ramp, with the transmitted to the interior through the adjacent atrium. Using designated modules, CEA can be designed there as a PFSL and vertically multiplied on the first and second floor as VF. This approach represents the most viable design scenario, owing to lower energy use for lighting (Çakir & Şahin, 2015; Kozai, Niu, & Takagaki, 2015; Nadal, Alamús, et al., 2017) and the increased productivity of an agricultural system lit by sunlight (Jenkins, 2018). The scale of the CEA operation should be enlarged by installing hydroponic units on the entire area of the first floor. That is possible in the form of a PFSL as the north-eastern and north-western elevations are permeable, while the south-western elevation is partly permeable. Thus, the sunlight transmitted to the interior of the multi-storey garage would benefit crop cultivation and reduce energy used for lighting systems. To enclose the building for controlling the internal environment, existing cladding materials should be complemented with glass cladding or ETFE foil. However, the installation of permeable materials to create a controlled environment for plant growth increases the initial financial investment, which, especially in the case of temporary up-cycling for UF, may be too high. Therefore, a second approach would be to use shipping containers and multiply them vertically and horizontally within the levels analysed, thus developing a PFAL without the need for enclosing the garage. Finally, this section of the car park could be enclosed with solid materials, and a PFAL developed. Another possibility for integrating CEA within the existing structure of the garage is recognised inside the atrium. This area could be utilised as a greenhouse, extending from the ground floor to the rooftop. Due to the limited availability of space, a single-span greenhouse as an uneven-span or Quonset shape greenhouse should be installed. However, developing CEA in this location would reduce sunlight transmission to the south-western section of London Road Car Park and increase the costs related to energy use for lighting required for plant growth in a PFAL. The materials which could be selected for the external skin of the greenhouse include glass, ETFE foil, semi-rigid plastics, plastic films and acrylic panels. Owing to the requirement to improve the aesthetics of London Road Car Park, the use of glass or ETFE foil is recommended.

The architectural analysis shows that the three elevations of London Road Car Park can be up-cycled for FFs. Considering the orientation of the garage, it becomes clear that the south-eastern elevation offers a viable opportunity to maintain the productivity of an FF throughout the year. Developing an FF in the proposed location would benefit the aesthetics of the building. Improving the aesthetics of the north-eastern and north-western elevations should focus on modernisation and installation of cladding materials in a way that allows for retaining the vertical concrete components unique to this modern movement garage. The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the internal and external areas of London Road Car Park is shown in Tables 27 and 28.

Table 27: The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the internal area of London Road Car Park

	Area [m^2]					
Level	CEA	Uses supplemental to CEA	Social uses	Circulation	Existing use	Total area
0	859.5	0	2140	1294	0	4293.5
1	2990.2	0	0	1742	0	4732.2
2	2092.1	0	662	1631.6	0	4385.7
3	0	0	0	0	4880	4880
Total	5941.8	0	2802	4667.6	4880	18291.4
%	32.50%	0.00%	15.00%	25.50%	26.70%	100%

Table 28: The quantitative analysis of the adaptive reuse scenario developed regarding the opportunities to implement CEA in the external area of London Road Car Park as FFs

	Vertical area [m^2]	
Elevation	FF	Total area
NE	0	1055
SE	468	468
NW	0	468
SW	0	0
Total	460	1991
%	23.10%	100%

7.4.3. Application of the environmental phase of the guide

Criterion: The architecture of the modern movement car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of the CEA operation

Step 1: The identification of the environmental opportunities and limitations for the adaptive reuse of London Road Car Park for CEA

In this step of the environmental phase of the guide, data from the planning phase is used as the basis for exploring the opportunities and limitations for implementing resource-efficient technologies and alternative energy technology options in the process of up-cycling the multi-storey garage for CEA operation. The results of the planning phase of the guide revealed that the crucial environmental drivers and motivations for repurposing London Road Car Park for CEA are clustered around the aim to reduce the adverse environmental impact of the current food supply system and urban development. While the planning phase of the guide focused on the urban scale of up-cycling the inner-city car parking structure for CEA, the environmental phase of the guide explores the architectural scale of the concept. The specific drivers and motivations identified in the planning phase include improved water use efficiency, improved building energy efficiency, sustainable architecture, energy-efficient productive architecture and enhanced closed cycles. In this step of the environmental phase of the guide, these drivers and motivations are used as objectives for analysing the environmental opportunities and limitations defined by the experts in Chapter 5 in the context of London Road Car Park.

The first opportunity identified in the guide is implementing resource-efficient technologies and alternative energy technology options in the process of up-cycling the London Road Car Park for CEA operation. This includes the optimal management of the indoor microclimate, installing energy-efficient lighting (LED lighting) and a lighting control system, regenerating alternative freshwater sources, rainwater harvesting, solar power systems (e.g. PV panels), wind power systems (e.g. Wind Assured system), ground sourced heat pumps, using biomass and developing a closed-loop plant cultivation system. The second opportunity is to create technical synergies between the CEA operation and other uses located within and upon the structure. Such a symbiotic relationship could enable the exchange of energy, water and heat, and the reuse of CO_2 and O_2. These opportunities contribute to improved water use efficiency, improved building energy efficiency and enhanced closed cycles as the key drivers and motivations relevant for the architectural scale of the proposed adaptive reuse for CEA. Applying these technologies would allow up-cycling the modern movement structure as an energy-efficient productive and sustainable architecture, which reduces the adverse environmental impact of CEA associated with an excessive use of urban resources.

The significant limitation for the opportunities identified is the fact that innovative technologies may not be compatible with the existing infrastructure in London Road Car Park. A lack of the innovative technologies required for developing synergies between CEA installations and additional uses may create another technical barrier. The high initial costs of implementing resource and energy-efficient technologies, alternative energy technology options and technical synergies are economic limitations that may significantly reduce the integration of technologies aimed at reducing the demand of the CEA operation for urban resources. These constraints may limit the adaptive reuse of London Road Car Park as an energy-efficient productive and sustainable architecture.

Step 2: The analysis of opportunities for applying resource-efficient technologies and alternative energy technology options in the process of up-cycling London Road Car Park for CEA

The design scenario for the adaptive reuse of London Road Car Park for CEA operations, developed in the architectural phase of the guide, is a foundation for the investigation into opportunities to apply resource-efficient technologies and alternative energy technology options in this step of the environmental phase of the guide. First, for improving water use efficiency, a closed-loop plant cultivation system should be developed in the PFSL occupying the designated internal areas of London Road Car Park, the greenhouse located in the atrium and the FF. Regenerating alternative freshwater sources should be applied within all types of CEA operation. Although the rooftop of the multi-storey garage is occupied by three multi-family buildings and a sports field, the spatial potential for locating rainwater harvesting installations has been identified within these areas. Another opportunity is to implement water harvesting installations on the roofs of housing blocks, which allows the development of water recycling systems as a symbiosis between the facilities located within and upon the multi-storey garage. Second, for improving building energy efficiency, energy-efficient electric devices should be used within the CEA operation, for instance energy-efficient pumps and boilers, solid-oxide fuel cells and LED lighting systems. The greenhouse, which may be located in the atrium, should be developed as a closed or semi-closed system. The indoor microclimate within all CEA types proposed in the architectural phase of the guide should be managed to provide optimal environmental parameters for plant growth. As London Road Car Park is a multiple function structure, technical synergies should be developed between the CEA operation, other uses implemented while retrofitting the structure, and the multi-family buildings located on the rooftop level. Technologies which should be considered include heat exchange, reuse of CO_2 and O_2, as well as installing FFs for providing thermal comfort within the garage. Third, alternative energy technology options should be installed within and upon the car parking structure in order to reduce the reliance of the CEA installations on urban resources. An opportunity for installing BIPV has been identified on the south-eastern elevation. While this external area is allocated for an FF (architectural phase of the guide), BIPV should be integrated with the double-glazed façade which accommodates the FF. GIPV should be installed as a replacement for an element of the external cladding of the greenhouse. Another opportunity for improving the building's self-sufficiency is associated with the installation of BIWT. As London Road Car Park accommodates three multi-family buildings on the rooftop level, this limits the use of this area for locating a large-scale wind turbine due to potential noise pollution. Therefore, the integration of small-size wind turbines on the façade of the garage, or the use of the skin of a building or an exterior wall which is a large, unused area subjected to wind pressure, should be analysed in the next steps of the research, beyond the boundary of this thesis. Potential technologies may include the system developed by Park et al. (2015) or the Wind Assured system indicated during the interviews (Chapter 4). Other alternative energy technology options which should be considered include industrial heat exchange between the CEA operation and other uses located within and upon London Road Car Park or neighbouring buildings, geothermal energy and biomass use. The specific site analysis, technical details and spatial opportunities for implementing these technologies should be considered following the architectural project development proposed as the next stage of this research, beyond the boundaries of this thesis.

7.5. Summary of Chapter 7

In this chapter, the guide for the analysis of the adaptive reuse potential of inner-city modern movement car parking structures for CEA was applied to three strategically selected case studies. In the planning phase, the research has shown that in all cases these urban structures should be up-cycled for a mixture of uses clustered around CEA. The facilities developed should contribute to the objectives of each inner-city area. Therefore, after the analysis of planning documents, the key drivers and motivations for meeting the planning criterion were defined for each case study. However, several limitations in the planning context were identified, including a lack of policies in support of UF in the inner-city, the economic viability of the CEA operation, or potential air and noise pollution. In the architectural phase, flexibility, modularity and the accessibility of layouts were identified as the crucial opportunities for meeting the architectural criterion. Securing the structures and improving their aesthetics were identified as further actions required to justify the up-cycling of modern movement garages for CEA in inner-cities. The architectural limitations investigated include the structural capacity of the buildings analysed, the possibility to enclose them for CEA, adapting the structural elements for the new use, adjusting the circulation and providing evacuation routes for fire safety. Finally, based on the second step of the architectural phase of the guide, for each case study the initial architectural scenario was conceptualised. These scenarios were the foundation for the environmental phase of the guide application, which revealed that the multi-storey garages have different potentials for implementing alternative energy technology options and resource-saving systems, as well as for developing environmental synergies. This potential stems from the architectural features of the modern movement structures, including the structural and functional connections with other buildings or usages, and spatial opportunities. Even if they are identified, such possibilities can be limited by a lack of compatibility between new and existing infrastructure, the high initial costs of the technologies required and the need for further development for them to efficiently cooperate with CEA. The following chapter will discuss the findings from this research and answer the research questions.

Chapter 8: Discussion

8.1. Introduction to Chapter 8

This chapter summarises and critically evaluates the findings of the research in the context of exploring the up-cycling potential of inner-city car parking structures for CEA through a typological approach. First, the role of research for the design of CEA as an alternative use of modern movement garages is discussed. Second, based on the findings from Chapter 7, the adaptive reuse potential of these structures for CEA is evaluated from the planning, architectural and environmental perspectives relevant in the initial stage of architectural proposal development. Third, the chapter presents reflections on the application of the guide to the selected cases of inner-city car parking structures, and discusses the role of research by design in this process. Next, the formal structural similarities which alter the existing architectural typology to accommodate an innovative use as a response to changing urban demands are determined. Finally, the research problem is generalised in the architectural and urban context, and the potential for the emergence of an innovative architectural typology is discussed.

8.2. Role of research for the design of controlled environment agriculture as an alternative use of modern movement car parking structures

As Kimbell (2015) indicates, when solving an architectural problem, the designer should cooperate with several discipline-specific experts, potential users and other stakeholders who together contribute to the research, generation of knowledge and finally the design. Conducted in the first stage of this thesis, research for design is based on multidisciplinary criteria aimed at analysing the planning, architectural and environmental opportunities and limitations for up-cycling inner-city modern movement car parking structures for CEA. Through this exploratory investigation, consisting of a literature review of discipline-specific secondary sources and interviews with experts, secondary and primary data were collected and summarised in the form of a guide for the analysis of the adaptive reuse potential of modern movement garages for CEA. Including the knowledge generated from research for design in the design thinking process is crucial for exploring the up-cycling potential of these structures, due to several facts that arose during this research. First, the investigation has shown that the planning, architectural and environmental opportunities and limitations relevant for repurposing buildings for CEA have already been well explored, and do not have to be learned from scratch as stated by Jenkins (2018). The last two decades have seen increasingly rapid advances in the field of PFs and RTGs, especially the environmental viability of these UA operations. From the architect’s point of view, applying the existing knowledge documented through research for design is crucial for the viability of the adaptive reuse scenario conceptualised. However, while most types of CEA in urban settings have been investigated theoretically, some gaps in the knowledge can be identified, and these cause impediments to our understanding of the benefits of up-cycling urban structures for CEA, thus constraining the implementation of building-based UA from the planning, architectural and environmental perspectives. Second, the exploratory case study analysis has shown that the planning, architectural and environmental opportunities arising from the literature review are already in use in existing CEA operations. However, their application is site- and scale-specific. The case study research revealed that the knowledge generated cannot be generalized, but has to be preceded by analysis of the planning, architectural and environmental context of the existing urban structure. Based on such an investigation, specific solutions derived from research for design should be applied in the design process. Third, data generated through the research for design, and documented in the guiding tool, is crucial for informing architects with different levels of expertise how to frame and make moves within the design thinking process for addressing the aims of this thesis. The significant contribution of the research for design is the development of the planning, architectural and environmental criteria which should be met in order to retrofit these buildings for CEA, as well as the definition of opportunities and limitations for meeting these criteria. Applying the guide established allows for replicating these findings in the initial design proposal for up-cycling modern movement garages for CEA as an alteration to an existing architectural type, which emerges as a response to changing urban needs (Argan, 1963; Madrazo, 1995; Vandyck & Bertels, 2018). Therefore, research for design in this thesis creates a theoretical background, not only for identifying the adaptive reuse potential of these buildings for local food growing, but also for critically evaluating the inherent formal structural similarities developed between the series of case studies, and based on them, conceptualising the evolution of the architectural type rooted in the modern movement era.

8.3. The adaptive reuse potential of inner-city modern movement car parking structures for controlled environment agriculture

The explanatory investigation of strategically selected case studies conducted through the application of the guide enables the addressing of the first research question formulated in this thesis:

RQ 1: What is the adaptive reuse potential of inner-city modern movement car parking structures in planning, architectural and environmental terms, relevant at the initial stage of the architectural scenario development?

This question has been addressed by conceptualising the potential of multi-storey garages to meet the planning, architectural and environmental criteria specified in the guide.

8.3.1. Meeting the planning criterion

Meeting the planning criterion: *The local authority must allow up-cycling the inner-city modern movement car parking structure and accept CEA as a future use* depends on the objectives for the development of the city defined in its planning documents. Investigating these documents allows the identification of the key drivers and motivations which should be used as arguments for retrofitting a selected inner-city car parking structure for CEA when engaging with the local authority. The consideration of the opportunities and limitations in the first step of the planning phase of the guide revealed that a local authority would allow retrofitting an inner-city car parking structure, and accept CEA as a future use, if key drivers and motivations are clustered around the objectives of sustainable urban development in its three dimensions: social, economic and environmental. These urban development priorities were pointed out as being crucial for increasing the acceptance of UA from a stakeholder perspective (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015) as investigated in Chapter 4. To meet this expectation, the multi-storey garage cannot be up-cycled solely for food production. The structure has to be retrofitted as a mixed-use building. To contribute to the economic sustainability of the inner-city area, the structure should accommodate profitable businesses. Although the selection of businesses is context-specific, the case study analysis indicates that the chosen functions should contribute to the liveliness of the central area by attracting residents and tourists. Thus, through the selection of businesses, the up-cycling of the car park can benefit the social sustainability of the area, for instance by including workshops and schools for food cultivation and cooking, exhibition spaces or restaurants. At the same time, the selection of businesses can influence the environmental sustainability of the urban area. This contribution to the development goals of the city can be done by choosing enterprises which are linked to food processing, distribution and sales. Such facilities could minimise the emissions related to the transport of the product for processing and selling. Enabling local distribution of the food cultivated would reduce food miles and contribute to the self-sufficiency of the city, thus decreasing dependence on the global food system. Although the adaptive reuse of inner-city car parking structures as mixed-use buildings reduces the space which can be used for CEA, it brings significant benefits for the area. The case study research has shown that the selection of facilities at the initial stage of the development of the architectural proposal plays a significant role in contributing to the three dimensions of urban sustainability, and generating social, environmental and economic drivers and motivations for retrofitting modern movement garages for CEA.

The crucial areas of social sustainability, defined in the development objectives of the cities analysed, which can be achieved when up-cycling car parking structures for CEA, include improved social cohesion and the health of urban residents. To contribute to these goals, food cultivation has to be open to the public, and encourage residents to engage in farming activity. While the literature reviewed has shown that residents are interested in UF as an environment for community building and empowerment (Jenkins, 2018; Lovell, 2010), the shortage of allotments in urban areas can be addressed by providing space for community farming. Organising workshops and guided tours within the development would bring consumers closer to food production, and educate them in healthy eating choices and habits. The uses which contribute to these priorities include food cultivation and cooking workshops, restaurants or spaces for experiments and creativity focused on food.

To meet the economic priorities of cities, CEA should be developed as a long-term economically viable activity, which offers new business, income, employment and marketing opportunities, improves regional value chains (Cerón-Palma et al., 2012; Mulligan et al., 2018; Sanyé-Mengual et al., 2016; Specht et al., 2015) and opens up opportunities for new inter-divisional and/or cross-sectional collaborations (Mulligan et al., 2018). A contribution towards these goals can be made by adopting circular economy principles, extending revenue opportunities by implementing uses supportive of food production (e.g. food processing, distributing and selling), involving farmers from the region in collaborative marketing, and developing local distribution channels.

The environmental objectives of urban areas can be met by reducing the adverse environmental impact of the current food supply system and urban development. On an urban scale, the main benefits include reduced food miles and lower pressure on agricultural land. While CEA is associated with a high demand for urban resources (Kozai, 2013; Sanyé-Mengual et al., 2016; Specht et al., 2015), on the architectural scale, the application of passive technologies which save and recycle resources as well as producing energy is crucial for reducing the environmental impact of the proposed up-cycling. A significant idea is the development of synergies between CEA operations and other uses in accommodating and neighbouring buildings (Gould & Caplow, 2012; Nelkin & Caplow, 2008; Thomaier et al., 2014). This is especially relevant when a multi-storey garage is developed in a multiple-function building, such as Prince Street Car Park, which is structurally and functionally connected to a hotel. In such cases, the environmental synergies should be maximised, for instance through the exchange of greywater and heat. Developing alternative energy technologies, resource-efficient technologies and environmental synergies with other uses or buildings would contribute to the adaptive reuse of inner-city modern movement garages as resource-efficient, productive architecture.

Another result arising from the explanatory case study analysis is the idea of including research activities in the proposed development. While social, economic and environmental sustainability are the crucial objectives defined in planning documents, research into topic areas of current relevance would contribute not only to the viability of the CEA operation, but also to the enhancement of the local food system and the resilience of urban communities. The proposed research areas include resource use efficiency, nature-based solutions in cities, innovative food production techniques, the circular economy and the food-water-energy nexus. Involving research activities in multi-storey garages retrofitted for CEA has the potential to create a space for experiments and creativity as an innovation which attracts investors.

The application of the planning phase of the guide to the case studies revealed that improving the aesthetics of multi-storey garages is one of the priorities defined in planning documents. Specht et al. (2015) has shown that aesthetic improvement of the structure is one of the arguments highlighted by stakeholders for enabling the development of building-based agriculture. The modern movement architecture of car parks is often not valued as unique, but considered *low-quality post-war development* (Bristol City Council, 1993, p. 16), which distorts the perception of the neighbourhood (Bristol City Council, 1993). Retrofitting these buildings creates an opportunity to improve the perception of an inner-city garage by reusing it with an alternative function, which affects its aesthetics. This may be done by greening the external skin of the building, for instance through FFs and RTGs, and modernising the building. At the same time, retaining the garage protects the unique character of the streetscape and contributes to the continuity of the urban fabric.

From the planning perspective, the adaptive reuse potential of inner-city car parking structures is reduced by several limitations. Planning documentation supports building-integrated agriculture (Bristol City Council, 2011, 2014), however it does not mention CEA as a possible site allocation in itself, but links it to new developments and green infrastructure as a facility which brings benefits to the community. Thus, UA is seen as an opportunity to activate urban residents and improve community cohesion, rather than enhancing the local food supply within cities. Such an approach limits the acceptance of up-cycling inner-city modern movement garages for CEA. This issue is further enhanced by the fact that there are no existing examples of this proposed adaptive reuse. The innovative character of the adaptive reuse may raise concerns regarding the social, environmental and economic viability of up-cycling car parking structures for CEA. Regarding social viability, the crucial argument includes the development of other, more required uses, compared to UA, for instance housing. From the environmental point of view, potential adverse environmental impacts caused by the proposed retrofit, such as an increased reliance on urban resources, or air and light pollution in the inner-city, may limit acceptance of the up-cycling scenario. Concerning the economic viability, the proposed building-based UF may be questioned due to the high initial and operating costs of CEA. This includes investment in hydroponic installations, alternative energy technology options, enclosing space for CEA and controlling the internal environmental parameters, as well as the high demand for resources which raises the costs of food production.

The findings discussed have significant implications for conceptualising the adaptive reuse potential of inner-city modern movement garages for CEA from the planning perspective. First, UF is not included as a site allocation in planning documents. This fact can become a significant constraint for meeting the planning criterion. Thus, changing planning policy and including various types of CEA in new development as well as in the adaptive reuse of buildings would create an opportunity for developing building-integrated agriculture as a secondary food source. Second, the contributions of the proposed adaptive reuse to the social, environmental and economic sustainability of the city are equally important. Defining the specific key drivers and motivations around these areas would significantly contribute to meeting the planning criterion defined in the guide. Additional benefits can be achieved if research activities are included in the scenario, and the aesthetics of the modern movement garage are improved. Third, while car parking structures should be up-cycled as mixed-use buildings, investment has to be carefully planned before this is implemented in an urban setting. Therefore, a greater number of experts, stakeholders and potential users should be involved in the design process to gather all of the data required for designing not only the CEA operation, but also additional uses around food production, processing, distribution and consumption. Finally, as the literature review indicated, building-based UA is seen as a temporary use of buildings (Sanyé-Mengual et al., 2016; Specht & Sanyé-Mengual, 2017), CEA operations and additional uses have to be designed in a way that allows them to be transported to alternative locations if the decision is made to demolish the car parking structure and replace it with a more profitable investment. This requires innovative design thinking, not only regarding building-based UA, but also the new uses implemented within the development.

8.3.2. Meeting the architectural criterion

Meeting the architectural criterion: *the architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities* depends on the individual architectural and structural features of the multi-storey garage in question. Although this research investigates the specific architectural typology of buildings designed in the modern movement era for car parking, each of these structures is characterised by a unique architectural design. Thus, the opportunities and limitations included in the architectural phase of the guide have to be analysed in the context of the specific multi-storey garage. The results of the planning phase of the guide provide data relevant for accomplishing the two steps of the architectural phase. The crucial finding is that multi-storey garages have to be up-cycled as mixed-use buildings. Therefore, the potential for these buildings should be investigated by exploring their architectural and structural features, considering the requirements of CEA and the other uses defined in the planning phase.

The application of the architectural phase of the guide to the case studies of three modern movement car parking structures in the UK shows that the up-cycling potential of these buildings for mixed-use development focusing on food production lies in their flexibility, modularity and accessibility. Exploring these features allows for the conceptualisation of the quantitative potential of a multi-storey garage for implementing CEA in the internal and external areas. The flexibility of layouts for the functional arrangement of space for CEA, including internal space for PFALs and PFSLs, arises from the distances between the structural elements which divide space vertically and horizontally. The structural supports in multi-storey garages are laid out in the form of a regular grid of columns or walls, thus offering various opportunities which can be used in the design thinking process for exploring architectural approaches in the initial stage of developing the adaptive reuse scenario. The open layouts benefit the adaptive reuse of the car parking structure for food production by enabling the transmission of sunlight to the interior, which opens the way for the consideration of various architectural scenarios for implementing CEA. The internal space can be retrofitted for a PFSL or a PFAL. There are several architectural approaches which should be considered before making design decisions on the type of CEA. This thesis aims to investigate the adaptive reuse potential of inner-city modern movement car parks for a viable CEA operation, thus in the process of the application of the guide, the scenario developed was the one considered the most viable in terms of productivity and energy-efficiency, based on the theoretical findings from the research for design. Applying the second step of the planning phase of the guide showed that three scenarios can be conceptualised. First, when deciding to enclose the external elevations with permeable materials (glass, ETFE), a PFSL can be developed. The exploratory research conducted in the first part of this thesis shows that this approach represents the most viable design scenario, owing to lower energy use for lighting (Çakir & Şahin, 2015; Kozai, Niu, & Takagaki, 2015; Nadal, Alamús, et al., 2017) and the increased productivity of an agricultural system lit by sunlight (Jenkins, 2018). However, the installation of permeable materials to create a controlled environment for plant growth increases the initial financial investment, which, especially in the case of temporary up-cycling for UF, may be too high. Therefore, a second approach would be to use shipping containers and multiply them vertically and horizontally within the car parking structure, thus developing a PFAL without the need for enclosing the garage. This type of CEA increases the use of energy for lighting, and may not represent a viable scenario over a long term perspective (Tsitsimpelis et al., 2016), although it was recommended by one of the experts interviewed for this research. Finally, the car parking structure can be enclosed with solid materials, and a PFAL developed. However, this type of CEA is considered highly dependent upon urban resources, especially energy, which reduces the validity of the agricultural operation in the inner-city area (Jenkins, 2018; Kikuchi et al., 2018, 2018; Kozai, 2013; Ting et al., 2016). This type of enclosing an UF operation in the central urban district would limit the visibility of CEA and could contribute to a reduction in its acceptance by the local authority and community. Although the theoretical investigation conducted in the first phase of this thesis proves that the first scenario (presented in chapter 7) represents the most viable architectural approach to the adaptive reuse of inner-city car parking structures for CEA, the phases of the research which follow this, and which are beyond the boundaries of this thesis, should consider the benefits and shortfalls of each system to select the most viable scenario in the specific economic and environmental circumstances, which are not known at this initial stage.

The potential in terms of flexibility plays a crucial role in making architectural decisions regarding the installation of CEA on the external parts of the multi-storey garage as RTGs or FFs. If the layout of the rooftop is empty, not occupied by any function or installations, without horizontal and vertical constraints, this space should be used for an RTG as this location offers maximum sunlight availability (Cerón-Palma et al., 2012; Montero et al., 2017; Pons et al., 2015). An RTG can be implemented as a single- or multiple-span greenhouse depending on the availability of space. However, the theoretical research conducted in the first part of this research revealed that the annual heating requirements of multiple-span greenhouses are lower that for single-span greenhouses (Djevic & Dimitrijevic, 2009; Hanan, 2017). Thus, if the spatial opportunity allows, multi-span greenhouses are recommended. A relevant piece of information for the architect in the initial phase of scenario development is that the length-width ratio of a greenhouse should be greater than one, and the roof angle should be designed between 25-30^{o} (Ahamed et al., 2018a). This knowledge allows a better exploration of the spatial potential of the rooftop of a garage regarding the specific architectural features of the CEA system. Another type which can be implemented on the external skin of the car parking structure is an FF. This productive installation in the cavity between the layers of a double skin façade should be developed on the south-oriented elevations (US 8,151,518 B2, 2012; Jenkins, 2018). Such a location increases the transmission of sunlight in all seasons of the year. However, the architectural investigation of the case studies shows that installing these productive systems is often limited in multiple-function buildings, due to the occupation of the southern façade by other uses. For instance, a hotel is attached to Prince Street Car Park in Bristol from the south. This constricts the implementation of FFs to the western and eastern elevation, where the productivity of the system is reduced in winter months owing to lower sunlight availability (US 8,151,518 B2, 2012; Jenkins, 2018). Despite this fact, the installation of an FF should be considered, as this system improves the energy efficiency of the accommodating building (US 8,151,518 B2, 2012; Jenkins, 2018; Stec et al., 2005) and benefits its aesthetics (e.g. in the case of the Isambard Brunel Car Park).

A limitation in terms of flexibility was identified in the floor-to-floor height of the multi-storey garages. This vertical constraint may indicate a requirement to partially take out concrete slabs to have double-height spaces or voids. For instance, the exploration of Prince Street Car Park revealed that the distance between the 4^{th} and 6^{th} floors is too low (2.40 m) to implement the required uses and needs to be modified. Further limitations to the flexibility of modern movement garages include staircases, ramps and lifts often located in the central areas of layouts. These elements are required for efficient circulation and should be integrated with the new use of the car parking structure. Moreover, on the ground floors, enclosed rooms are often identified, serving security and maintenance purposes. These spaces can be modernised for the same functions or for one of the facilities of a mixed-use building.

Their modularity supports the flexibility of layouts of the garages. It includes the vertical modularity of floors, and the module created by the layout of parking bays. Such a repeatability of layouts offers the possibility to take a similar architectural approach leading to the design of modular hydroponic units, which can be multiplied horizontally and vertically as VF. Including modular cultivation units in the design scenario offers the possibility for transporting them to another location with the same module within the car park, or to a different garage if required, for instance if the decision is made to demolish the structure.

The accessibility of the garage, associated with the presence of ramps developed for cars as well as staircases and lifts for people, was highlighted by the experts interviewed for this thesis as an opportunity to make the circulation of products and people efficient. The architectural analysis of the selected cases of inner-city multi-storey garages confirms this finding. While transporting the agricultural product in and out of the building is recognised as a constraint for building-integrated agriculture, mainly when an RTG is located on the rooftop of an urban structure (Cerón-Palma et al., 2012; Pons et al., 2015; Sanjuan-Delmás et al., 2018; Sanye-Mengual et al., 2015), the accessibility provided through the ramps to all levels of a garage enables the circulation of the agricultural product. Staircases and lifts provide the circulation elements used by staff and visitors. The efficiency of circulation in a specific adaptive reuse scenario should be calculated in the further stages of research, beyond the boundary of this thesis, when the uses and their locations are designed. Importantly, the staircases should be analysed in the context of the fire safety of the mixed-use development, and may require modification.

The accessibility of the car park is linked to its security. Securing the structure is necessary when implementing CEA and the uses distinguished in the planning phase of the guide to prevent unauthorised access. The architectural analysis revealed that the ground floor layout of the garages should be enclosed, and give access to authorised vehicles for the circulation of the agricultural product only. Circulation through staircases and lifts should be controlled on each level. As the areas of the multi-storey car parks designated for social uses may be open during working hours, the CEA area should be secured at all times to prevent theft, damage and the spread of disease.

An opportunity to improve the aesthetics of modern movement structures was identified as crucial, due to the findings that arose from the interviews in Chapter 5. Such a demand is supported by the application of the planning phase of the guide, where the analysis of planning documents revealed that the uniqueness of the modern movement architecture represented by the multi-storey garages is not considered beneficial for the inner-city. It is perceived rather as brutalist architecture which interferes with the character of the urban district. Therefore, aesthetic improvement should be included in the adaptive reuse scenarios. This can be achieved by modernising the structure, and greening the building by installing FFs. However, the architectural features of a specific building should be investigated to retain its unique elements, such as the external concrete staircases unique to Isambard Brunel Car Park in Portsmouth, or the unique concrete geometric composition on the elevations of Prince Street Car Park in Bristol.

The research into the limitations for the adaptive reuse of the inner-city car parking structures for CEA revealed that the structural conditions of the garage have to be analysed. The investigation includes concrete slabs, columns, structural walls, staircases and ramps. Such an analysis is beyond the scope of this thesis, as a structural engineer should conduct this before the architect proposes the specific architectural design. When exploring the limitations caused by the requirement to enclose the building, it is clear that creating a controlled environment entails the application of cladding materials and enclosed structures for plant cultivation on the building, such as FFs or a greenhouse on the rooftop. The installation of these systems may be limited by the structural capacity of the garage (Jenkins, 2018) or the location of other uses or installations on the rooftop and elevations (Specht et al., 2015). The investigation into the structural elements indicates that the existing floor-to-floor height can represent a limitation for the placement of hydroponic units and additional uses specified in the planning phase of the guide's application. In the case studies analysed, the height does not constrain food cultivation; nonetheless, in one case it creates a limitation for additional uses, mainly those accommodating a large number of people. Thus, the investigation should be advanced when specific design decisions regarding the location of uses are being made, in the next stage of the development of the architectural proposal, beyond the scope of this thesis. The exploration of the existing circulation within the case studies shows that it is efficient for the proposed function. Vehicular access is provided through internal ramps, while pedestrians can access via staircases and lifts. However, specific analysis should be conducted when making architectural decisions regarding the location of internal walls and doors to accommodate different uses, as this will affect the horizontal and vertical evacuation routes and may trigger the need to propose alterations for fire safety.

8.3.3. Meeting the environmental criterion

Meeting the environmental criterion: *the architecture of the car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of the CEA operation* depends on the individual architectural features of the modern movement garage and the architectural scenario developed in the architectural phase of the guide. The theoretical investigation conducted in the first stage of this research indicated the resource-efficient technologies and alternative energy technology options which are linked to CEA operations in the existing literature. When implementing a PFSL or a PFAL within the garage, an RTG or an FF on the structure, a closed-loop plant cultivation system should be developed (Cerón-Palma et al., 2012; De Gelder et al., 2012; Gould & Caplow, 2012; Putra & Yuliando, 2015; Sanjuan-Delmás et al., 2018; Vadiee & Martin, 2012) and the optimal management of the indoor microclimate maintained (Ahamed, Guo, & Tanino, 2018b; Caplow & Nelkin, 2007; Hemming et al., 2017; Kozai, 2013; Kozai et al., 2015; Thomaier et al., 2014; Van`t Ooster, Van Henten, Janssen, Bot, & Dekker, 2008). Regenerating alternative freshwater sources (Ellingsen & Despommier, 2008; Specht et al., 2013) and rainwater harvesting (Ackerman et al., 2013; Sanyé-Mengual, 2015; Thomaier et al., 2014) should be applied within all types of CEA operation. For improving building energy efficiency, energy-efficient electric devices should be used within the CEA operation, for instance, energy-efficient pumps and boilers (Ahamed et al., 2018b), solid-oxide fuel cells (Kikuchi et al., 2018; Semple et al., 2017) and an LED lighting system (Bantis et al., 2016; Barta, Tibbitts, Bula, & Morrow, 1992; Bergstrand et al., 2016; Hernández et al., 2016; Matsuda et al., 2016; Singh et al., 2015; Ting et al., 2016; Yeh & Chung, 2009). The case study research revealed that the application of alternative energy technology options might be possible through the use of BIPV (Despommier, 2010), which can be integrated with the external cladding of the building or RTG as GIPV (Allardyce et al., 2017; Amaducci et al., 2018; Dupraz et al., 2011; Miyamoto et al., 2009). Integrating PV panels within the skin of the building arose as a significant alternative for locating them on the rooftop, as this space offers maximum sunlight transmission and should be used for an RTG. Another opportunity for improving the building's self-sufficiency was associated with the installation of BIWT (Despommier, 2010). While the case study research revealed that the rooftop areas of multi-storey garages are often occupied by other usages, and if not, should be designated for an RTG, these findings limit the location of BIWT to the elevations. Therefore, the integration of small-size wind turbines on the façade of the car parking structure, the use of the skin of a building, or an exterior wall which is a large, unused area subjected to wind pressure, should be analysed in the next step of the research, beyond the boundaries of this thesis. Potential technologies may include the system developed by Park et al. (2015) or the Wind Assured system recommended by one of the experts during the interviews. Other alternative energy technology options which should be considered include industrial heat exchange between the CEA operation and uses located within and upon the modern movement garage or neighbouring buildings, geothermal energy (Despommier, 2011; Fabrizio, 2012; Kikuchi et al., 2016; Nadal, Llorach-Massana, et al., 2017; Sanjuan-Delmás et al., 2018; Togawa et al., 2014) and biomass use (Hepbasli, 2011; Kikuchi et al., 2016, 2018; Nadal, Llorach-Massana, et al., 2017). The specific site analysis, technical details and spatial opportunities for implementing these technologies should be considered after the architectural project is proposed, beyond the boundaries of this thesis.

The final opportunity identified was to develop technical synergies between the CEA operation and other uses (Sanyé-Mengual, 2015; Specht et al., 2013; Thomaier et al., 2014) located within and upon the structure. In the garages developed as a part of a multi-functional building, environmental synergies can emerge between various facilities, for instance Prince Street Car Park and the hotel, or London Road Car Park and the residential buildings located on its rooftop. According to the literature analysed, such a symbiotic relationship enables the exchange of energy, water, heat and reuse of CO_2 and O_2. These opportunities contribute to improved water use efficiency (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2015), building energy efficiency (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2015) and enhanced closed cycles (Sanyé-Mengual et al., 2016) as the key drivers and motivations relevant at the architectural scale for the adaptive reuse of the multi-storey garages for CEA. Applying the proposed technologies increases the up-cycling potential of modern movement car parking structures as energy-efficient productive and sustainable architecture, which reduces the adverse environmental impact of CEA associated with an excessive reliance on urban resources.

The application of the opportunities defined may be limited by a lack of compatibility between the innovative technologies and existing infrastructure in the modern movement garages. This concern was indicated by Thomaier et al. (2014) and 40 percent of the interviewed experts. Thus, the technical coherence of the existing and innovative installations should be investigated before design development. Another constraint may be a lack of technologies required for creating synergies between CEA operations and other uses (Thomaier et al., 2014). The high initial costs of implementing resource and energy-efficient technologies, alternative energy technology options and technical synergies was identified as an economic limitation that may significantly reduce the installation of several technologies (Cerón-Palma et al., 2012; Specht et al., 2013; Thomaier et al., 2014). These constraints may create a barrier for the adaptive reuse of modern movement garages as energy-efficient productive and sustainable architecture.

8.4. Reflections on the application of the guide to the selected cases of inner-city multi-storey garages

The overarching aim of the guide for the analysis of the adaptive reuse potential of inner-city car parking structures for CEA is to enable replicating the theoretical findings from this research in the process of exploring the up-cycling potential of modern movement garages for CEA, and to lead the design thinking process when developing the initial design scenario. The primary method applied to conceptualise such a scenario is the design thinking process. Rowe (1987) states that the nature of the problem-solving process itself shapes the solution. In a similar vein, Schön (1983) indicates that framing and making moves in the design thinking process is vital for solving the problem, while Lawson and Dorst (2009) argue that the level of expertise among architects plays a crucial role in shaping the final design scenario. The results of the guide's application to the selected case studies corroborates these ideas. The viability of the guide lies in the exploratory analysis of secondary and primary sources, which provide data used as the foundation for the tool's development (phases, criteria, steps) and as a theoretical framework integrated within that tool (data in step 1 and step 2 of the three phases of the guide). Phases, and the steps specified within them, inform the design problem solving process and suggest tools for the investigation. Thus, the design thinking process in Chapter 7 was informed by the guiding tool which led the development of the initial design scenarios for the proposed adaptive reuse. The critical evaluation of findings from the guide's application to the three case studies, summarised as a response to Research Question 1 in section 8.3, became the foundation for investigating the inherent formal structural similarities which alter the modern movement architectural type to accommodate an innovative use in the urban environment.

Some of the findings arising from the application of the guide to the case studies suggest multiple solutions. The final scenarios developed in Chapter 7 are based on the results of the exploratory stage of this research, which investigated and documented the opportunities and limitations for the planning, architectural and environmental efficiency of the proposed UA operation. From the perspective of these findings, the conceptualised scenarios are characterised by being the most viable from the planning, architectural and environmental perspectives. Such results, while preliminary, may require modifications if more data is provided in the later stages of the architectural research, beyond the boundaries of this thesis. For instance, while this thesis does not include the economic, environmental or social analysis relevant for the future of car parking structures, the application of the guide may generate different results if the findings of such investigation were to be included.

8.4.1. Role of research by design in investigating the adaptive reuse potential of modern movement car parking structures for controlled environment agriculture

The main aim of the thesis states a problem of an innovative architectural nature, which is addressed by the architect and from the architect`s perspective. Thus, thinking through architecture, in this case the architecture of modern movement car parking structures, is the primary method applied. Research by design *presents a model for thinking the generalising and rule building while simultaneously projecting towards the future* (Jorgen et al., 2013, p. 336) and these were the overarching priorities when conceptualising the objectives of this research and deciding on the methodology.

The research by design, applied to investigate the adaptive reuse potential of modern movement garages, was led by the guide developed from the research for design. This amalgamation of research approaches opened up the possibility to explore and summarise secondary and primary data relevant for the proposed up-cycling for CEA, which, through the application of the guide, were included in the research by design process. This combination of methods allowed for basing the research by design on existing knowledge, and revealed that the innovative character of the proposed up-cycling arises not from developing CEA within buildings, as this is already well explored, but placing this food cultivation system within a specific type of inner-city structures - modern movement garages. Thus, research by design enabled the analysis of these buildings concerning the planning, architectural and environmental opportunities and limitations already known (1st steps of the three phases of the guide) which pointed toward the past in order to project their transformation into the future by conceptualising specific up-cycling scenarios (2nd steps of the three phases of the guide). Finally, research by design made normative contributions by allowing the drawing of conclusions on the adaptive reuse potential of modern movement car parking structures for CEA, and the subsequent evaluation of the inherent formal structural similarities, which alter the existing architectural typology to accommodate an innovative use as a response for changing urban demands.

8.5. Determining the formal structural similarities altering the existing architectural typology for controlled environment agriculture

The application of the guide to the strategically selected cases of inner-city modern movement car parking structures generated analogies between the planning, architectural and environmental findings.

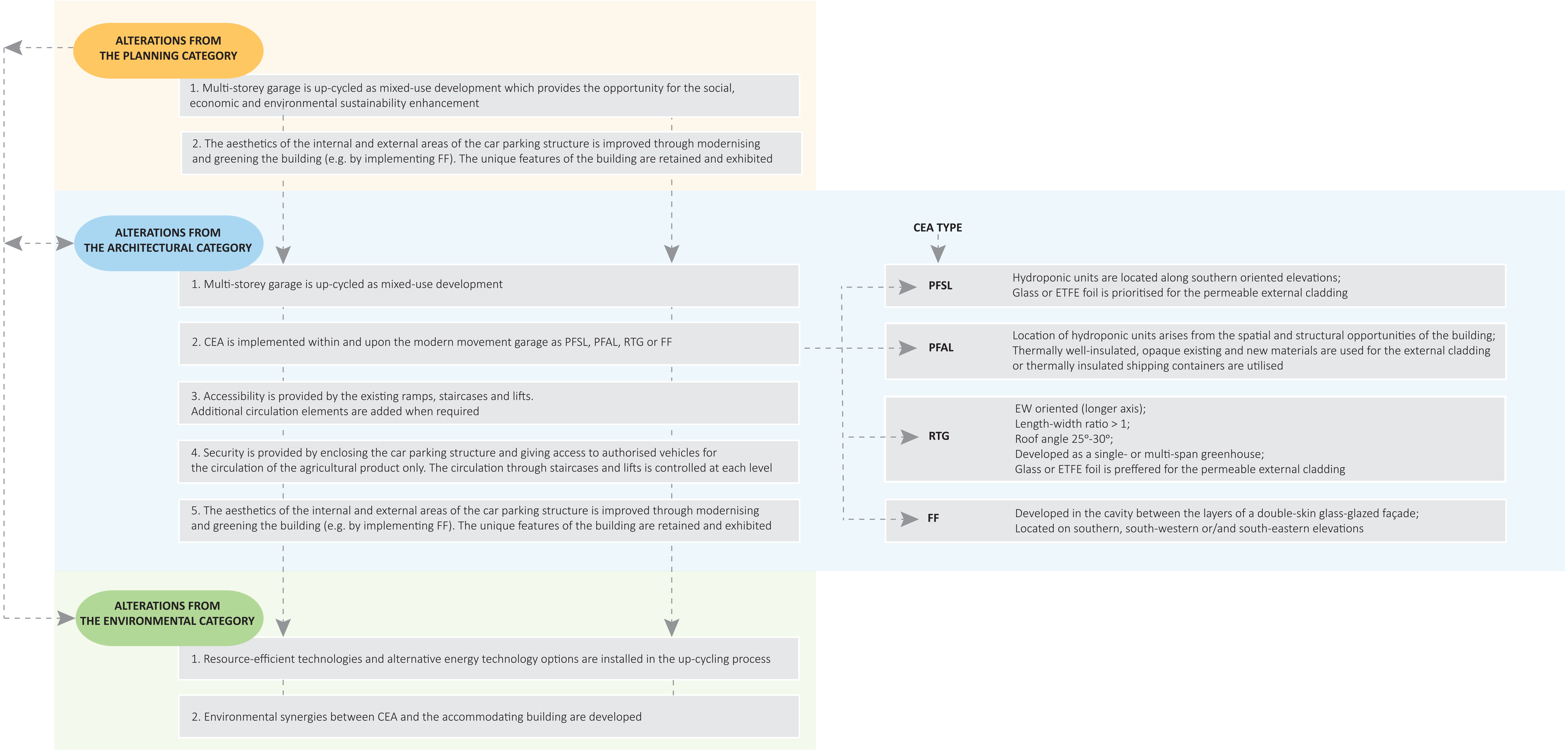


Figure 62: Formal structural similarities identified, which alter the existing architectural typology within the categories of this research, particularities identified for CEA

Analysing these analogies addresses research question 2:

RQ 2: Which formal structural similarities arise from the analysis of the up-cycling potential of modern movement car parking structures that alter the existing architectural type in order to accommodate controlled environment agriculture?

This question was answered from the perspective of the planning, architectural and environmental phases of the guide's application (Figure 62).

The first inherent formal structural similarity which arose from the planning phase as the foundation for the type-alteration is the requirement to accommodate a mix of uses clustered around CEA within the car parking structure. Modern movement garages have to be up-cycled as mixed-use developments to create opportunities for the enhancement of the social, economic and environmental sustainability of the city. However, the selection of uses is context-specific and should be consistent with the future vision of the inner-city area defined in its planning documents. Thus, the adaptive reuse processes may contribute in different ways to the three pillars of urban sustainability to meet the objectives of cities. The opportunities explored in this research include improved social cohesion, the improved health of urban residents, providing space for innovation and research, the long-term economic viability of the CEA operation, the reduced adverse environmental impact of the current food supply system and urban development. These areas of improvement can be reinterpreted as the key drivers and motivations investigated in Chapter 4, and then used as arguments for the implementation of the concept when engaging with the local authority at the initial stage of the architectural proposal development.

The second thing of particular note is that the aesthetics of the internal and the external areas of the car parking structure are improved through modernising and greening the building (e.g. by implementing FF). At the same time, the unique features of the modern movement garage, for instance the external cladding structure in Prince Street Car Park, are retained and exhibited. Such an approach allows the protection of the modern movement architecture while adaptively reusing it for an alternative function. It also contributes to the retention of the character of the inner-city area and the continuity of the urban fabric.

The primary formal structural similarity arising from the architectural phase of the guide relates to the finding from the planning phase indicating that multi-storey garages should be up-cycled as mixed-use developments. This requires applying architectural analysis in the design thinking process, which identifies opportunities and limitations arising from the existing architectural typology. The crucial areas of investigation defined through this research included flexibility, modularity, accessibility, security, the structural conditions and capacity of the modern movement car parking structures, as well as strategies to enclose the car parking structure, adapt the structural elements and circulation to the requirements of the new functions and ensure fire safety.

CEA can be developed within the internal parts of the modern movement garage as a PFSL, a PFAL or the symbiosis between these two types of building-based UA. If the opportunity exists, the external areas are occupied by an RTG and FFs. The design of these productive installations is based on the findings from this research. If the selected type of CEA requires sunlight access, it is south-oriented, as such a location benefits from the availability of sunlight, which contributes to the productivity and energy use efficiency of the food cultivation system (Jenkins, 2018; Specht et al., 2015). Hydroponic installations in a PFSL can be developed within the internal areas attached to the southern-located elevations (Jenkins, 2018). Similarly FFs, developed in the cavity between the layers of double-skin façades, can be attached to the southern, south-western or/and south-eastern elevations (US 8,151,518 B2, 2012; Jenkins, 2018). If the roof of the multi-storey garage is unoccupied, it is designated for an RTG, which is EW oriented (longer axis) due to maximised solar radiation transmission and improved energy efficiency (Ahamed et al., 2018a; Chandra, 1976; Dragicevic, 2010; Papadakis et al., 1998; Stanciu et al., 2016). The length-width ratio of the RTG is greater than one, while the roof angle is designed between 25-30^{o} for improved energy efficiency (Ahamed et al., 2018a). If the spatial and structural potential of the garage allows, the RTG is developed as a multi-span greenhouse, where the annual heating requirements are lower than in a single-span greenhouse (Djevic & Dimitrijevic, 2009; Hanan, 2017). If a PFAL is developed, the location of hydroponic units is based on the analysis of the spatial and structural opportunities and limitations of the accommodating structure. Alternatively a PFAL can be designed in thermally insulated shipping containers (Tsitsimpelis et al., 2016), which are vertically and horizontally multiplied inside the garage.

The external cladding materials for a PFSL and an RTG are summarised in Appendix B. However, due to the inner-city location and the high expectations for the aesthetic improvement of modern movement garages, glass and ETFE foil are mainly used for creating the controlled environment when the availability of sunlight is required. The adaptive reuse of a car parking structure for CEA benefits from good light transmission, heat retention and the durability of these materials, as well as the possibility of integrating them with PV panels (Despommier, 2011; Hu, Chen, Zhao, & Yang, 2017; Jelle et al., 2012; Keiler et al., 2005; Lai & Hokoi, 2015; Lau, Masih, Ademakinwa, Low, & Chilton, 2016; O'Hegarty et al., 2016; Peng, Huang, & Wu, 2011; Robinson-Gayle, Kolokotroni, Cripps, & Tanno, 2001). FFs can be developed in the cavity between the layers of a double-skin glass-glazed façade (US 8,151,518 B2, 2012; Jenkins, 2018; O'Hegarty et al., 2016; Stec et al., 2005). For a PFAL, the multi-storey garage is enclosed by thermally well-insulated, opaque materials (Kozai et al., 2015; Kozai, Ohyama, & Chun, 2006). In the up-cycling process, existing materials are integrated with new ones required for minimising the generation of material waste and for possible integration with PV or wind power systems (Hartman, 2001; Hestnes, 2002; Hu et al., 2017; Jelle et al., 2012; Kozai, 2013; Mandalaki et al., 2012; Park et al., 2015; Stathopoulos et al., 2018). If CEA is developed by using shipping containers, these should be thermally insulated (Tsitsimpelis et al., 2016).

Another architectural particularity is the circulation routes, which utilise the existing ramps for transporting the agricultural product, as well as staircases and lifts for other users. Additional staircases and lifts can be designed if the existing ones do not provide efficient circulation or evacuation routes in the mixed-use development. Moreover, the multi-storey garage is secured to prevent unauthorised access. The ground floor layout of the car park is enclosed and gives access to authorised vehicles for the circulation of agricultural products only. The circulation through staircases and lifts is controlled on each level. As the areas of the multi-storey garages designated for social uses are open during working hours, the CEA area is secured at all times to prevent theft, damage and the spread of disease.

The final architectural particularity - the improved aesthetics of the garage - recurs in the planning similarities identified. Although, these structures are characterised by a strong internal anatomy, and their design is rarely informed by the location, they are now considered relics of the modern movement era which represent unique features for this architectural typology (Henley, 2007). Up-cycling inner-city car parking structures for CEA addresses the requirement to improve the aesthetics of the garage, for instance by implementing FFs and modernising the building. Individual features developed in the modern movement era, such as the highly permeable geometric composition of X-components on the elevations of Prince Street Car Park in Bristol or the external concrete staircases of Isambard Brunel Car Park, are retained and given enhanced visibility for protecting the unique character of the building and commemorating its original function.

When eliminating the particulars relevant for up-cycling modern movement garages for CEA that arise from the environmental phase of the guide’s application, two things emerge. First, the adaptive reuse of inner-city car parking structures for CEA includes resource-efficient technologies and alternative energy technology options to minimise pressure on urban resources and the adverse environmental impacts of urban food production in a controlled environment. To contribute to these goals, various technologies are considered for application, including those arising from the theoretical investigation, and more innovative ones targeted at CEA which may be developed in the future (Specht et al., 2013; Thomaier et al., 2014). The selection of technologies is conducted after the specific analysis of the urban and environmental opportunities and limitations offered by the area investigated. After this exploration, the installation of the chosen technologies utilises the existing structure and materials of the building as well as the newly proposed materials, for instance if glass or ETFE glazing is installed, it is integrated with PV panels as BIPV, while the cladding of an RTG is developed as GIPV.

Finally, the adaptive reuse of modern movement garages for CEA develops environmental synergies with the accommodating building to further minimise the pressure on urban resources and the adverse environmental impacts of urban food production in a controlled environment, as well as reducing costs related to resource use. The existing technologies allow exchanging heat (Delor, 2011; Nelkin & Caplow, 2008; Pons et al., 2015), reusing CO_2 and O_2 (Delor, 2011), harvesting greywater (Ackerman et al., 2013; Sanyé-Mengual, 2015; Thomaier et al., 2014) and improving thermal comfort in the building by installing FFs (Jenkins, 2018; Stec et al., 2005). If the car park is a single function structure, neighbouring buildings are investigated regarding potential environmental synergies.

8.5.1. Synthesis of the alterations of the existing architectural typology for implementing controlled environment agriculture

The planning, architectural and environmental changes which have to be developed to alter the modern movement architectural type for accommodating CEA are to some extent interrelated. This mainly pertains to the planning phase, which plays an informative role for the architectural and environmental stages, as well as the architectural phase which indicates individual opportunities and limitations arising from some characteristics of a specific urban structure for the environmental stage. The overlap between the categories developed in this research reveals that, in the architect's work, the conceptualisation of the initial design scenario for repurposing the modern movement garages has to be done by investigating all three phases: planning, architectural and environmental. The key finding from the planning phase indicates that a modern movement car parking structure cannot be solely up-cycled for CEA, but to be accepted in contemporary inner-cities, a proposal for a mixed-use building has to be developed. Such an approach requires investigating the adaptive reuse scenario from the urban perspective, where opportunities for improving social, economic and environmental sustainability are explored. While the primary function arising from repurposing the existing architectural type is CEA, other uses should be compatible with food production. A design scenario that assumes the development of a hybrid structure as the outcome of the up-cycling process brings about significant opportunities for the city, including improved social cohesion, the improved health of urban residents, provision of space for innovation and research, the long-term economic viability of the CEA operation, the reduced adverse environmental impact of the current food supply system and urban development. However, to be realised on the urban scale, the decisions on the architectural alterations of the modern movement structure have to be made at the architectural level. Thus, the existing architectural type becomes the driver for architectural design and innovation in the city. Changes required to implement CEA are complemented with those needed to develop uses arising in the planning phase. Architectural analysis becomes a process which enables qualitatively and quantitatively examining the architectural capacities of the existing modern movement structure to be hybridized in usage. Alterations for accommodating CEA as the primary function require an innovative design approach, which in some of the cases examined derived from the rural agricultural solutions (RTG, PFSL), while in others turned to systems developed purposefully for CEA (FF, PFAL). Architectural analysis allows investigating the up-cycling potential of a specific modern movement structure for implementing such specific alterations, thus conceptualising the qualitative and quantitative evidence for the plausibility of the initial design scenario developed.

The alterations to the existing architectural typology arising from the planning and architectural phases became the foundation for the environmental investigation. The specific environmental solutions depend on planning and architectural changes. For instance, up-cycling a multiple-function structure offers opportunities for developing synergies with other uses, which allow exchanging resources (e.g. excess heat or greywater). If complemented with resource-efficient technologies and alternative energy technology options, such buildings would become a sustainable and productive architecture, which provides environmental sustainability benefits on the urban scale. Developing a hybrid structure, where all of the uses are gathered around CEA, enables efficient processing, selling and consumption, thus creating opportunities for reducing the adverse environmental impacts of the global food system and implementing an innovative secondary food source in cities. The specific adaptive reuse potential of a modern movement garage for CEA in terms of environmental alterations arises as an outcome of the analysis of the findings from the planning and architectural investigations.

8.6. Generalisation of the research problem in the architectural and urban context: the potential emergence of an innovative architectural typology

In the current discourse around urban regeneration, the contribution of adaptive reuse projects to the three pillars of sustainability: social, economic and environmental, is seen as the primary objective (Couch, Fraser, & Percy, 2003). On the architectural level, repurposing buildings can bring such benefits by implementing specific uses, materials or infrastructures, which are selected after context-specific investigations, investor demands, available technologies and innovative ideas arising as the results of design thinking (Lehmann, 2016b). While maintaining the balance between social, economic and environmental sustainability in up-cycling projects is the critical element relevant from the stakeholders' perspective, in fact it is a challenging process which at its roots should explore changing urban requirements. Investigating a city as a continually evolving organism allows for recognising its current needs, and adapting existing architectural types. However, in several stages of this research, especially the literature review and interviews, it became clear that architectural innovations in terms of function, materials and technologies are challenging to progress in the planning context. This is because the decision makers' interpretation of how architectural design can meet urban sustainability objectives is lacking in progression. The decision on the reduction of a use which has become superfluous, such as car parking in inner-city areas, and the implementation of an innovative uses with the potential to benefit the resilience of the local food system as a secondary food source, is constrained by a lack of understanding and research into the evolving nature of the urban environment. Therefore, CEA practices in cities arise mainly as bottom-up initiatives, where the adaptation of existing buildings is seen as the most viable approach due to the costs of up-cycling and technology, as well as the questionable permanency of the project. The idea of a more profitable investment than UA in the current urban context is the crucial reason why the adaptive reuse of modern movement car parking structures for CEA is seen as a temporary option. The implementation of uses such as housing is more significant than UA from the perspective of urban needs. However, as more and more people live in cities, and the operation of the global food system already causes adverse social, economic and environmental impacts, the decision makers' focus on the location of food production may play a crucial role in the future urban food supply. Local food production becomes even more significant in the face of unforeseen threats, such as a shortage of certain foods or increased purchasing caused by the emergence of a pandemic (DEFRA, 2009). For instance, during the pandemic in the UK in spring 2020, the Country Land and Business Association indicated a significant shortage of workers, leading crops rotting in fields, resulting in fewer products in stores. In this context, innovation and experimentation in the area of CEA, as a secondary food source in cities, should be encouraged and supported by decision makers. Thus, the relationship between agriculture and architecture, such as ZFarming, BIA or VF, should be better investigated to initiate a shift in thinking around the benefits delivered by technical UA systems to urban sustainability.

The initial design scenarios developed in this research for repurposing the modern movement car parking structures selected for CEA were elaborated on the basis of the relationship between architecture and nature connected by technological solutions. The natural environment and processes that occur in the living word often inspire contemporary architecture as they provide knowledge on how to deal with the ecological and technological issues which arise between the natural and urban environment (Di Raimo, 2014). Environmental mimicry and biomimicry design trace relationships which are present in nature to apply them to architecture, and create symbiosis between the living word and artificial structures (Benyus, 2002). Thus, nature and natural systems become integral elements of an architectural form, and often dominate not only its functional organisation but also architectural appearance. In this research, the information provided by nature plays a slightly different role. Modern movement car parking structures constitute a typology which is rooted in particular previous urban requirements, and these dominate the design, including architectural appearance, functional organisation and structural solutions. The up-cycling potential of these garages for CEA consists of identifying how the symbiosis between the existing building and nature can be realised on the urban and architectural scales. In the natural world, the symbiotic relationship between organisms allows for their mutual support and co-evolution within the environment, which they contribute to defining while the environment continually evolves due to these interactions (Di Raimo, 2014). Thus, urban needs and the existing architectural type constitute opportunities and limitations for developing a symbiotic relationship with nature.

In this research, the architectural type, present in the urban environment from the modern movement era, becomes the catalyst for the invention to accommodate nature. The environmental parameters for plant growth provide information on the alterations required. However, it is the existing architecture that defines to which extent these can be applied to develop viable a CEA operation. This research has identified significant organisational and functional differences between the uses of the past and those proposed for the future. Thus, the alterations explored trigger the need for a transformation of the existing architectural type as an invention on the urban and architectural scale, which enables accommodating an innovative function. In this context, CEA could become the driving force which gives the modern movement type significance beyond its original purpose. The analysis of the up-cycling potential of the selected inner-city multi-storey garages for CEA conceptualised in this research indicates that the alterations required become the stimulus for the new design process, which not only induces the evolution of the existing type, but may also lead to the development of an innovative architectural typology which supports local food production as a secondary food source.

8.7. Summary of Chapter 8

Chapter 8 discussed the findings from this thesis. First, the role of research for the design of CEA as an alternative use of modern movement car parking structures was elaborated as a method to investigate and summarise the existing knowledge on this research area, as well as to generate primary data through the exploratory case studies. Then the first research question was addressed by conceptualising the adaptive reuse potential of inner-city modern movement car parking structures for CEA through the evaluation of the opportunities and limitations to meet the planning, architectural and environmental criteria defined in the guide. The application of the tool enabled a comparison of results, to the detriment of trialling the full potential on diverse cases. Therefore, it was possible to hypothesise that the application of the guide in the design thinking process leads to the alteration of the architectural typology of modern movement car parking structures in order to accommodate an innovative food production operation as a response to changing urban demands. The crucial method applied to evaluate such changes within the existing typology was research by design, which enabled the analysis of multi-storey garages concerning the known planning, architectural and environmental opportunities and limitations (1st steps of the three phases of the guide), which point toward the past in order to project their transformation into the future (2nd steps of the three phases of the guide). Research by design made normative contributions by allowing the conclusion of the adaptive reuse potential of modern movement car parking structures for CEA (RQ1) and then determining the formal structural similarities which arise from this investigation that alter the existing architectural typology to accommodate CEA (RQ2). The discussion on the research problem in the architectural and urban contexts indicates a lack of understanding of the role which CEA may play in the local food supply of growing cities as the primary constraint that may limit the implementation of the initial design scenarios developed for up-cycling modern movement car parking structures for CEA. The role of the environment in the conceptualised proposals plays an informative role, while urban needs and the existing architectural type constitute opportunities and limitations for developing a symbiotic relationship with nature. Finally, the potential for the emergence of an innovative architectural typology, which alters the type rooted in the modern movement era for the enhancement of the local food supply was identified. Chapter 9 concludes this thesis and gives recommendations for future research.

Chapter 9: Conclusions and future research

9.1. Introduction to Chapter 9

By bringing together the many arguments defined over the course of this research, the final chapter summarises the key findings, and shows in which way the set objectives of the thesis have been met. It discusses the significance of the results and the contribution of the thesis, as well as recognising the limitations of the research. Finally, recommendations for future research work are made.

9.2. Summary of findings and conclusions from this research

This research hypothesised that firstly CEA is one of the adaptive reuse options to which inner-city modern movement car parking structures can be put; and secondly, that up-cycling these garages for CEA leads to the alteration of the existing architectural typology as a response to changing urban demands. Therefore, the thesis aimed to explore the adaptive reuse potential of inner-city modern movement car parking structures for viable CEA operations from the architect's perspective, and to determine the alterations required within the existing architectural typology to accommodate this innovative use in the urban environment. The objectives of the investigation included researching and documenting the planning, architectural and environmental opportunities and limitations for up-cycling inner-city modern movement garages for CEA, adapting the knowledge generated for the development of the guide for the analysis of the adaptive reuse potential of such structures for CEA, applying the guide to specific test-cases of inner-city modern movement car parking structures to identify the up-cycling potential of these garages for CEA, and critically evaluating the inherent formal structural similarities developed between the series of case studies in order to conceptualise the alterations to the existing architectural typology. What follows is a detailed summary of the most relevant findings which emerged while attaining each of the objectives listed above, and the conclusions drawn.

Objective 1: To research and document the planning, architectural and environmental opportunities and limitations for up-cycling inner-city modern movement garages for CEA

This thesis meets objective 1 through its literature review, exploratory case study analysis and the interviews with experts. The key findings of the literature review include the existing knowledge on the planning, architectural and environmental opportunities and limitations for the adaptive reuse of buildings for CEA. The analysis of the literature on the planning considerations which are relevant at the initial stage of the scenario development revealed that planning opportunities and limitations are set within the social, environmental, economic, technical and aesthetic domains of urban development listed in Table 7. Planning and policy evolution is another crucial area which can benefit from the implementation of building-based CEA. The exploration of local planning documents allowed an understanding of the planning context and identification of the essential possibilities and constraints represented by the urban district analysed. By investigating how up-cycling inner-city multi-storey garages for CEA can contribute to the objectives of the specific urban area, the key drivers and motivations for accepting food cultivation as an alternative use for these modern movement structures can be defined. Such a conceptualisation of the meaningful impacts of the proposed retrofit on urban life at the initial stage of the design proposal's development has the potential to outweigh the risks and uncertainties associated with building-based CEA.

The findings from the literature review on the architectural opportunities and limitations for the adaptive reuse of buildings for CEA initiated the definition of types of CEA in urban environments (Fig. 25). Up-cycling urban structures for CEA can be done by converting the interior for farming operations, and utilising the envelope. In internal areas, CEA can be developed as a PF, which utilises natural sunlight (PFSL) or uses solely artificial lighting or a hybrid lighting system (PFAL). On the external areas of a building, CEA operation can be installed as an RTG or an FF, integrated into the elevations. The basic units of analysis relevant for the development of an initial design scenario for up-cycling buildings for CEA arising from this typological perspective include an architectural form for CEA, the orientation of that form, the materials to enclose a space for CEA and the structure of the building adaptively reused for CEA. The results of the thorough literature review into these areas of investigation are presented in Table 8.

The findings from the literature review on the environmental opportunities and limitations for repurposing buildings for CEA determined resource-efficient technologies and alternative energy technology options which can be installed when up-cycling urban structures for CEA. While the pressing concerns of high resource- and energy-use by CEA significantly limits the implementation of these productive systems (Ackerman et al., 2013; Graamans et al., 2017; Kozai, 2013), the development of such technologies can reduce adverse environmental impacts (Kozai, 2013). Therefore, the selection of specific installations should be made in the initial stage of the up-cycling process. Applying resource-efficient technologies and alternative energy technology options is considered a way to justify the use of urban structures for CEA (Ackerman et al., 2013; Al-Chalabi, 2015; Romeo et al., 2018). The summary of the resource-efficient technologies and alternative energy technology options explored in this research for the adaptive reuse of buildings for CEA is presented in Table 9.

Objective 1 is further addressed by the exploratory case study analysis conducted to validate the findings from the literature review. For each case study, the key drivers and motivations for the adaptive reuse of building for CEA were determined through the framework of the results from the literature review. This investigation confirmed that the drivers and motivations identified are located within the social, environmental, economic, technical, aesthetic, partnership and policy domains of urban development. The architectural analysis of case studies (Fig. 34) shows that in all cases, the structures chosen for adaptive reuse are located in inner-city areas. This investigation corresponds with the planning phase and with the literature review, and indicates that such an urban approach offers social, economic and environmental opportunities, which outbalance other urban locations (e.g. peri-urban regions). The benefits include the increased visibility of the farming operation in the inner-city, the proximity to customers and shorter product transportation distances (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2015). Therefore, the conceptualisation of the key drivers and motivations has the potential to deliver more robust evidence for accepting CEA as the future use of an inner-city structure when compared to other locations within the city.

The urban farms selected for the case study research represent different approaches to the architectural form accommodating CEA. Grow Bristol was developed as a PFAL in two shipping containers. The Biospheric Project consists of two CEA types, which are a PFSL and an RTG. The PFSL was implemented within a derelict factory, while the RTG occupies the roof. In BIGH Ferme Abattoir the productive area is located in a multi-span RTG. The investigation into the orientation of the buildings accommodating the case studies reveals that in the PFAL, represented by Grow Bristol, the orientation of the structure did not influence the design decisions, as the CEA operation relies solely on artificial lighting. The longer axis of Irwell House, accommodating a PFSL, is NS located. The hydroponic units were developed along the south, east and north elevations with windows; however, the northern location was designed as an experimental location. This orientation of the building is indicated in the literature review as being optimal for sunlight transmission for CEA (Albatayneh et al., 2018), while placing growing installations along the south, east and west elevations is recommended (Jenkins, 2018). An RTG was developed on Irwell House as a Quonset shape single-span system which is NW/S oriented. In BIGH Ferme Abattoir, the RTG was implemented as even-shape, single-span, L-shape structure, which is oriented NE/SW and NW/SE. The literature review revealed that the EW orientation of a greenhouse is the most beneficial, due to maximised solar radiation transmission and improved energy efficiency (Ahamed et al., 2018a; Chandra, 1976; Dragicevic, 2010; Papadakis et al., 1998; Stanciu et al., 2016). However, the case studies show that the location of an RTG is the result of a compromise between the beneficial orientation and the spatial and structural potential of the roof. Thus, the increased growing area in BIGH Ferme Abattoir, or structural capacity of Irwell House, was the crucial design consideration which led to the less advantageous orientation of the RTGs.

The investigation into the external cladding materials indicates that the selection of the urban structure affects the development of the specific typology of building-based CEA. In Grow Bristol, the controlled environment for plant growth was created within an up-cycled shipping container. The outer cladding material does not transmit the sunlight to the interior. Thus, the UA operation was developed as a PFAL. The Biospheric Project was located within and upon an obsolete building. The existing windows on the second floor transmitted sunlight to the internal area, which created the opportunity for developing a PFSL. The rooftop potential was used for the location of an RTG as the transparent structure. In BIGH Ferme Abattoir, the CEA operation was implemented on the unoccupied roof of the existing building, which offered high flexibility for selecting the external cladding for CEA. In this case, the architectural approach to up-cycle this area for UF led to the development of an RTG, which maximises sunlight transmission beneficial for plant cultivation. Moreover, the architectural exploration of the case studies showed that the intended scale of the CEA operation affects the selection of the structure and the specific cladding material. The bigger the size of the CEA operation, the higher the requirement for transparent cladding materials. The main reason for this is lower demand for energy for lighting, which brings the environmental benefits associated with a minimised reliance on urban resources, and the corresponding economic savings.

Grow Bristol, as a PFAL, was developed in an up-cycled thermally insulated shipping container, explored in the literature for such applications due to its high rating for insulation (Tsitsimpelis et al., 2016). In the Biospheric Project, a PFAL was implemented in a derelict factory where the existing cladding materials were retained, which provide environmental and economic benefits (Lehmann, 2010). The cladding material for the RTG is PE-based film (Ahamed et al., 2018b; Cemek et al., 2006; Montero et al., 2017). The RTG developed in BIGH Ferme Abattoir was made of glass (Ahemd et al., 2016; García Victoria et al., 2012; Hemming et al., 2017; Montero et al., 2017; O'Hegarty et al., 2016; Semple et al., 2017; Swinkels et al., 2001).

The analysis of the structure of the case studies indicated opportunities and limitations relevant to the initial design stage of the adaptive reuse of buildings for CEA. In Grow Bristol, the four walls of the shipping container created the horizontal limitation for locating hydroponic rows. The height of the structure was the constraint for the vertical multiplication of hydroponic tiers. The existing walls, grid of columns and the distance between slabs on the second floor affected the location of growing units in the derelict factory building (Jenkins, 2018; Tomlinson, 2015) in the

Biospheric Project. The structural limitation for the placement of the RTGs in the Biospheric Project and BIGH Ferme Abattoir was the area of the roof. Another constraint is the structural capacity of the accommodating building, which, as indicated by Jenkins (2018) and Sanyé-Mengual (2015), can become the fundamental limitation for the scale of the UF operation. For instance, the load-bearing capacity analysis of the obsolete building chosen for the Biospheric Project revealed that the implementation area of the PFSL and the RTG was reduced by the structural capacity of the building and the requirement to reinforce the construction (Jenkins, 2018). Thus, the structural capacity assessment of the accommodating building is crucial for making informed decisions regarding the spatial potential of the building for CEA.

The exploration of resource and energy-efficient technologies and alternative energy technology options in the urban farms selected for the case study research indicated that the environmental benefits derived through the installation of such technologies are well understood. In all of the analysed cases, the optimal management of the indoor microclimate and closed-loop cultivation systems played a crucial role in resource-saving. However, the scale of the CEA operation bolsters the requirement for sustainable technologies and environmental synergies between uses, due to the possibility to reduce resource use, which results in lower economic costs.

Interviews with experts were conducted to narrow down the research to the specific type of urban structure: modern movement multi-storey garages located in inner-city areas. The primary data generated led to the identification of criteria which should be met in order to develop a viable design scenario for the proposed adaptive reuse. The crucial criterion that arose from the analysis of responses to the planning category of questions is that the local authority must allow up-cycling the inner-city modern movement car parking structure and accept CEA as future use. The opportunities identified by the experts to meet this criterion include improved social cohesion, the improved health of urban residents, the provision of space for innovation and research, the long-term economic viability of the CEA project, the reduced adverse environmental impacts of the current food supply system and urban development, and the improved aesthetics of the car parking structure. The limiting factors for meeting this criterion were constraints for the approval of the change of use of the multi-storey garage for CEA, a lack of knowledge on building-based CEA, a lack of space protection for UA, a lower acceptance of CEA than community food growing, and the high initial and operating costs of CEA. The detailed findings are presented in Table 17. The criterion that arose from the architectural category of responses is that the architecture of the modern movement car parking structure must offer a space for the implementation and efficient operation of CEA installations and associated facilities. The specific opportunities and limitations for meeting these criteria which arose from the results of the interviews are presented in Table 18. The opportunities included flexibility of layouts for the functional arrangement of space for CEA, modularity of plans for the possibility to design modular hydroponic units and alternative energy installations which are easy to transport to another car parking structure, accessibility for people and vehicles, security, and the improved aesthetics of the multi-storey garage. The limiting factors for meeting this criterion were the structural conditions of the concrete building, the requirement to create a controlled environment in the garage, the adaptation of the structural elements for CEA installations and natural light access, adaptations to circulation and fire safety. The environmental criterion which arose from the interviews was that the architecture and infrastructure of the modern movement car parking structure must allow implementing resource-efficient technologies and alternative energy technology options in the up-cycling process to reduce the environmental impact of the CEA installations. The opportunities and limitations for meeting this criterion are presented in Table 19. The first opportunity identified was the installation of resource-efficient technologies and alternative energy technology options, while the second was the development of environmental synergies between CEA and other uses. The limiting factors were a possible lack of compatibility between the innovative infrastructure and the existing infrastructure, high initial costs related to the implementation of resource and energy-efficient technologies, alternative energy technology options and technical synergies, as well as a lack of innovative technologies for developing synergies between CEA and the additional uses.

The interviews concluded the theoretical part of this research answering Objective 1. Before the empirical investigation commenced, based on the data obtained, the guide for the analysis of the adaptive reuse potential of inner-city modern movement garages for CEA was developed (Figures 35, 36, 37).

Objective 2: To adapt the knowledge that has been generated for the development of the guide for the analysis of the adaptive reuse potential of inner-city modern movement garages for CEA

The overarching aim of the tool is to enable the replication of the theoretical findings from this research in the process of exploring the up-cycling potential of modern movement garages for CEA, and to lead the design thinking process when developing the initial design scenario. The guide points out planning, architectural and environmental criteria, steps and tools, as well as summarising and presenting data that allows for the architectural exploration into the various scenarios for repurposing multi-storey garages for socially, environmentally and economically viable CEA operations. The tool is based on the primary data gathered through interviews (Chapter 5) and the secondary data obtained in the literature review (Chapter 4), and was validated through the exploratory case study analysis. While the planning phase of the guide explores the urban dimension of the proposed up-cycling, the architectural and environmental phases investigate the concept on an architectural scale. The primary outcome of the guide is the conceptualisation of the initial design scenario for repurposing modern movement garages for CEA. The guide was developed to be applied by architects in the initial stage of the design thinking process to collect data for further investigation into the concept, which is beyond the boundaries of this thesis. The recommendations for the guide's development which arose as conclusions from the analysis of the interviews are presented in Chapter 5. The tool is shown in Figures 35, 36 and 37. The guide was applied to the three case studies of inner-city modern movement garages, which enabled meeting Objective 3 of this thesis:

Objective 3: To apply the guide to specific test-cases of inner-city car parking structures in the UK to identify their up-cycling potential for CEA

The application of the guide led to the conceptualisation of the adaptive reuse potential of the three selected inner-city modern movement car parking structures in the UK in terms of meeting the planning, architectural and environmental criteria as well as quantifying the possibility to implement CEA in the internal and external areas. The exploration of the findings from this process allowed for defining the initial design scenario for these buildings as productive urban structures. These results, which address Objective 3, are presented in Chapter 8, section 1.3.

From the application of the guide, two conclusions arose. First, the use of the tool developed in this thesis does not deliver an unequivocal proposal, but rather a series of possible avenues, which when based on existing knowledge offer viable initial scenarios for the adaptive reuse process. Thus, in the cases analysed, there are some alternatives for meeting the planning, architectural and environmental criteria. Regarding the planning phase, the crucial finding is that the modern movement garage should be up-cycled for a mix of uses clustered around local food production. The selection of the specific uses becomes the foundation for generating the key drivers and motivations as a result of the planning phase of the guide's application, and therefore should contribute to the objectives of the city, focused around social, economic and environmental sustainability. Various facilities can be chosen to deliver benefits in these domains, which can result in the development of a series of adaptive reuse scenarios. In the architectural phase, the variability of the initial design proposals lies in the development of the CEA operations. For instance, while the research identified a PFSL as being more environmentally and economically sustainable than a PFAL, due to lower energy use for lighting resulting in financial savings, the conceptualised scenario could propose to implement a PFAL if preferred by the future users. Similarly, in the environmental phase, the selection of the specific technologies and environmental synergies varies depending on the specific requirements of the CEA operation and the financial situation of the users. Thus the steps, tools and data included in the guide can be applied to the garage being analysed in different ways, depending on the priorities of the urban area and the future user. This conclusion confirms the statement that designers cannot work as *the main agents in design* (Kimbell, 2015, p. 301). Therefore, the next stages of the design thinking process, aimed at further investigation into the architectural problem, require the involvement of several discipline-specific experts, potential users, and other stakeholders who together contribute to the research, generation of knowledge and the final design. Such a diversity of engaged actors emerges from the fact that the outcome of the architectural process is expected to deliver a viable but previously unknown solution in the urban environment.

The first conclusion leads to the second conclusion arising from the guide's application, which indicates that the analysis of a modern movement car parking structure is context-specific, because it defines the conditions for long-term functioning, which depend on the fusion between existing knowledge on CEA and the individual planning, architectural and environmental context of the modern movement car parking structure. The first phase of the guide relies on the analysis of local planning documents, where the objectives of the specific urban environment can be identified and investigated in the context of the adaptive reuse of the selected car parking structure. While the case study analysis revealed that the objectives of the cities vary, although they are focused around social, economic and environmental sustainability, the strategies for generating the key drivers and motivations for retrofitting modern movement garages in different urban environments are diverse. The role of the architectural context, embodied in the architectural design of the multi-storey garage being investigated, influences the results of the second phase of the guide's application. Exploring the opportunities and limitations defined in the first step, as well as applying the existing knowledge on CEA in the second step, delivers different results, which depend on the individual design features of different buildings located within a single architectural typology. Similarly, in the environmental phase, although the potential for implementing alternative energy technology options and resource-efficient technologies was identified in all of the case studies explored, context-specific limitations and opportunities were identified, which arose from the architectural features of the building analysed. Importantly, while each phase of the guide's application influences the one which follows, the results show that the planning context of the inner-city car parking structure affects the design solutions defined in the architectural framework, and these two factors impact the environmental decision context.

These conclusions from the application of the guide are considered the strengths of this research, since they enable a high level of flexibility in determining the up-cycling scenarios. Such flexibility in the initial stage of the architectural proposal's development opens up alternatives for the further steps of the investigation, aimed at a specific scenario which then can be designed and implemented. Thus, the application of the guide initiates the design thinking process for the adaptive reuse of inner-city modern movement garages for CEA by informing architects and enabling the replication of the theoretical findings from this research. The conceptualisation of the final design scenario, which is beyond the boundaries of this thesis, is flexible, context-specific, and expected to produce quantitative data regarding its actual contribution to the local food supply.

Objective 4: To critically evaluate the inherent formal structural similarities developed between the series of case studies to conceptualise the alteration of the existing architectural typology

The typological approach, adapted as a research methodology in this thesis, aims to identify the adaptive reuse potential of inner-city modern movement garages for CEA to critically evaluate the inherent formal structural similarities developed between the series of case studies, and based on them, to conceptualise the alterations within the architectural typology that are required for accommodating the innovative function. This objective is met in Chapter 8, section 1.5 (Figure 62). Three conclusions arose from this investigation. First, urban dynamics, residents' changing needs and global threats (including the adverse impacts of the global food system) require trade-offs between a multitude of factors to foster a different mindset in the decision makers involved in the making of cities. It has to be acknowledged that adaptive reuse within specific architectural typologies may lead to an innovative type-alteration, which allows a building rooted in previous architectural eras to meet changing urban demands. Thus, the architecture of modern movement car parking structures becomes the driving force for innovation. As the literature review indicated that a lack of knowledge on the benefits and up-cycling potential of buildings that are no longer needed in an area is the primary reason which leads stakeholders towards the decision to demolition a structure and replacement it with new investment, an acknowledgement of the continuous evolution of the urban environment and the generation of specific data for adaptive reuse are required to maintain this process within existing architectural typologies in a socially, environmentally and economically sustainable manner.

Second, it is an acceptable decision to determine the formal structural similarities which alter the existing architectural typology to accommodate an innovative use in the initial stage of the architectural scenario development. This conclusion arises from the fact the application of the guide does not deliver an unequivocal proposal, but rather a series of possible avenues, which when based on existing knowledge offer viable initial scenarios for the adaptive reuse process. The initial stage of the design thinking process allows for defining the inherent particularities in terms of the planning, architectural and environmental features and decisions within which a more specific design can be developed in the subsequent stages of research. Thus, the alterations to the existing architectural typology are broad in their interpretation and offer flexibility within themselves for the further development of the concept. This is crucial since the adaptive reuse scenario led by the design thinking process is context-specific. Thus, the final up-cycling projects can differ significantly while still being located with one architectural typology.

Finally, the alterations required within the architectural typology analysed, which arose from application of the architectural phase of the guide to the case studies, define the aspects crucial for the primary purpose of the up-cycling process - urban food production in a controlled environment. However, in the current urban context, the planning and environmental particularities identified within the investigated car parking structures justify this activity in the inner-city. This is because it delivers benefits for urban sustainability, which outbalance local food cultivation from the perspective of the stakeholders. Thus, alterations to the existing architectural typology arising from the planning and environmental phases provide the primary drivers and motivations, which the architect should conceptualise in the initial stage of design scenario development for repurposing modern movement garages for CEA.

9.3. Significance of the findings and contribution of the thesis

This thesis contributes to the conceptualisation of the up-cycling scenario of inner-city modern movement garages in the UK context by identifying the adaptive reuse potential of these structures for CEA as one of the uses to which they can be put, and defining the alterations required within the architectural typology to accommodate this innovative use. The knowledge generated contributes to the discourse on the adaptive reuse of buildings for alternative functions as a response to changing urban needs, and as a method to deliver social, economic and environmental sustainability benefits to the urban environment. The investigation is based on research for design, which makes a contribution to knowledge by exploring and summarising secondary data through the literature review on the planning, architectural and environmental opportunities and limitations for repurposing buildings with CEA from the architect's perspective, and validates the findings through an exploratory case study analysis of existing CEA operations developed in the adaptive reuse process of inner-city structures. The primary investigation, conducted through interviews with experts, narrowed down the research focus to inner-city modern movement car parking structures as the first comprehensive investigation on the topic. The knowledge explored through research for design plays a critical role in deepening the understanding of the proposed up-cycling, including allowing the reuse of car parking structures for CEA by local authorities and decision makers, designing a viable architectural proposal, and selecting sustainable technologies which reduce the reliance of the productive system on urban resources. This theoretical investigation generated the data required for the development of the guide for the analysis of the adaptive reuse potential of inner-city modern movement garages as the first tool conceptualised for this purpose. The guide informs architects in the initial stage of the design proposal development about the planning, architectural and environmental criteria, steps and tools, as well as summarising and presenting data that contributes to the exploration into the various scenarios for up-cycling multi-storey car parking structures for viable CEA operations. When applying the planning phase of the tool to the three strategically selected cases of inner-city modern movement garages in the UK, it became clear that from the stakeholders' perspective, the contribution of the proposed retrofit to the objectives defined for the city in planning documents benefitted the acceptability of the concept. As these objectives are clustered around the enhancement of the social, economic and environmental sustainability of the urban environment, the investigation revealed that the acceptability of the proposed up-cycling would be greater if the proposal includes a mix of uses clustered around local food production and supply. This finding extends the understanding of the design approach, which should be applied in the initial stage of the proposal development to conceptualise the key drivers and motivations relevant from the planning perspective, and brings significant insights into the two subsequent phases of the guide. The architectural phase of the guide informs about the process of analysing the modern movement garages, conducted as research by design. The architectural investigation of plans through the framework of the data generated through research for design expands the architect's understanding of the formal and structural features of the car parking structure. It allows their interpretation as opportunities or limitations for the proposed retrofit. In the design thinking process, such an exploration is crucial for making informed decisions leading to the conceptualisation of a viable architectural scenario. The environmental phase informs about the opportunities and limitations for selecting installations that can be implemented for reducing the environmental burdens of the CEA operation. As the extensive use of urban resources is considered a significant limitation for implementing this type of UA (Despommier, 2010; Kozai et al., 2006; Specht et al., 2013), investigating the available technologies and including them in the initial design scenario helps to improve predictions of the impact of the proposed retrofit. Taken together, these findings contribute to the current literature on BIA (Caplow & Nelkin, 2007), ZFarming (Specht et al., 2015; Thomaier et al., 2014) and VF (Despommier, 2010) as the adaptive reuse of urban structures for CEA operations.

This thesis conceptualised the alterations that are required within the modern movement architectural type to accommodate CEA, and indicated the potential for developing an innovative architectural typology for urban food production. The findings contribute to research into the evolving nature of existing architectural typologies which arise as a response to the changing requirements of urban environments. In this investigation, the typology which evolved, although explored for CEA, is located within the discourse of mixed-use development as sustainable, productive architecture. Therefore, this work has been one of the first attempts to thoroughly examine the adaptive reuse potential of an existing architectural typology for a mixture of uses implemented to enhance the local food supply.

This study lays the groundwork for future research into the advanced stages of the conceptualisation of an architectural proposal for up-cycling inner-city modern movement car parking structures for CEA. While the application of the guidelines developed in this thesis opens up a series of possible avenues for further investigation into the proposed concept, several design scenarios could be explored depending on the social, economic and environmental aims of the specific user selected in the subsequent stages of research, beyond the boundaries of this thesis. Simultaneously, the significant role of the planning context, indicated as a conclusion of this research, will influence higher-level design decisions.

9.4. Challenges encountered in the development of the thesis

A major challenge which arose was the inter-disciplinary nature of this investigation, which required the utilisation of data from disparate fields of knowledge, including architecture, rural and urban agriculture, as well as environmental sciences and technology. The review of the literature within these disciplines had to be limited to sources which explored the types of CEA that are currently being investigated in the urban context. Next, the aspects relevant to the adaptive reuse of buildings had to be selected. As the research was conducted from the perspective of an architect, and by an architect with experience in practice, the literature review was limited to sources relevant in the initial phase of the investigation into the up-cycling process.

The challenge encountered in the development of the thesis was the perception of the research in terms of innovation. Due to the lack of specific knowledge and existing examples of up-cycling car parking structures for CEA, the experts invited for the interviews needed a more extended period to decide about their participation. The main argument for this was a difficulty in conceptualising such a scenario for the future of modern movement garages. Sharing the research proposal, plans of the multi-storey garages and the interview questionnaire helped to inform the potential participants and encouraged them to be interviewed. In the end, fifteen interviews were conducted, while 26 interview invitations were distributed. Thus, the decision to limit the number of interviewees to fifteen was not dictated by time issues, but by the perception of the research area in terms of innovation.

Another challenge was the selection of the case studies, both exploratory and explanatory. While to an extent, the existing building-based CEA operations represent a homogeneity of features, this was required in this thesis to validate the types of CEA arising from the literature review.

However, a specific urban farm could only be chosen if the plans and knowledge of the operation were possible to obtain. The in-depth investigation into the selected case studies was uncertain due to difficulties in contacting the farms and obtaining the layouts. For all of the exploratory cases, the knowledge was based on online sources, while plans were sent by the urban farmers operating the farm. Similarly, the selection of the case studies for the explanatory analysis conducted through the application of the guide was expected to involve different urban and architectural contexts. The availability of layouts was a constraining factor again, as several of them are missing from city council archives. Therefore, the decision on the selection of modern movement garages which would enable a comparison of the results of the guide's application, to the detriment of testing its full potential on diverse cases, was a complex process involving the analysis of the context and verifying the availability of the plans.

9.5. Recommendations for further research

This thesis investigates the adaptive reuse potential of inner-city modern movement car parking structures for CEA in the initial stage of design development. Future studies on the topic are therefore recommended to advance the up-cycling scenarios, and gather more data required for a comparative LCA of the proposed up-cycling compared to demolition followed by new build. The focus of the work on a specific multi-storey garage would allow for deeply exploring its adaptive reuse potential. Such a study may lead to a detailed architectural design for a mixed-use building developed for local food production and supply. In the planning dimension of the concept, further work should include cooperation with the local authority and community to validate the implementation of the uses that arose from the planning phase of this research. In the architectural dimension of the concept, further research should include cooperation with other discipline-specific experts, who can provide more data on the development of the design scenario. For instance, the recommended study could bring crucial insights into the structural capacity of the garage, which could be an essential constraint for locating technical food systems within and upon the building (Jenkins, 2018). Thus, the results of this investigation will answer the questions which were not addressed in this thesis, including the productivity potential of the up-cycled modern movement car park. To advance the proposed adaptive reuse concept in terms of environmental sustainability, a further study with more focus on the resource-efficient technologies and alternative energy technology options is suggested. The specific site analysis, technical details and spatial opportunities for implementing these installations should be examined. The investigation should be conducted together with experts in environmental sciences and engineers to generate specific data on a reduction in the adverse environmental impact of CEA in urban settings, which is now highlighted as the primary constraint for this form of the local food production (Cerón-Palma et al., 2012; Sanyé-Mengual et al., 2016; Specht et al., 2013). Moreover, the analysis should include the potential to develop environmental synergies with other uses within the accommodating structure and neighbouring buildings. Cooperation with experts in this field may open new research opportunities, not only in architecture, but also environmental sciences and engineering.

After generating more data on the adaptive reuse potential of modern movement garages for CEA, the specific details of food cultivation and distribution should be investigated. This includes the selection of the type of hydroponic system, plant species to be cultivated in the hydroponic installations, technologies for creating the controlled environment and the specific parameters for the plant species cultivated, the distribution of the product, as well as the management and use of associated facilities (e.g. cooking school, grocery, restaurant). This future investigation into the opportunities located within various research disciplines would deliver knowledge on the productivity of the developed CEA operation, its specific contribution to the local food supply, shortening supply chains and reducing food miles.

While the first part of this research explored the planning, architectural and environmental opportunities and limitations for repurposing buildings for CEA, the data generated in Chapter 4 can be utilised for the exploration of the up-cycling potential of urban typologies other than car parking structures, for instance offices or industrial buildings. This would further contribute to the investigation into the transformation of urban structures into sustainable and productive architecture, which can be classified as BIA (Caplow, 2010; Caplow & Nelkin, 2007; Gould & Caplow, 2012; Nelkin & Caplow, 2008), ZFarming (Specht et al., 2013, 2015; Thomaier et al., 2014) and VF (Despommier, 2010, 2011). The exploration into such innovative typologies within the urban environment has the potential to contribute to the enhancement of the local food system, and simultaneously reduce the adverse social, economic and environmental impacts of the global food supply over a long-term perspective.

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APPENDIX A Supplementary data for Chapter 3

This appendix plays a supplementary role for Chapter 3: a literature review.

1. The literature review on the social, economic and environmental impacts of the global food system

   1.1. Social and economic implications of the global food system

The global food production system is continuously evolving to meet the ever-changing nutritional preferences and requirements of consumers across the world. Critical challenges within the global food sector include balancing product price versus quality, safety, demand and variety (Mc Carthy et al., 2018). The green revolution offered numerous tools to achieve this goal through addressing each of the significant areas in which food is produced, processed, stored, delivered and accessed. From the perspective of the agricultural industry, the primary purpose of this continuous restructuring is income generation and export enhancement, while sustenance, the nutritional quality of produced food and self-sufficiency are not a priority. When combining this attitude with the biased free trade, several social and economic issues arise. First, developed countries declare the support for the free trade, while subsidising their farmers. At the same time, agricultural producers in the developed world are encouraged to cultivate crops for export without any financial support and often struggle to compete economically with farmers from developed countries (Jenkins, 2018). This issue has been further advanced since the big retailers have started to implement private food standards and food safety norms. Lack of expertise to comply with such standards and financial difficulties often contribute to the marginalisation of poor and small countries, smallholder farmers and small and medium-sized enterprises (King et al., 2017; Webb, 2015). The lack of financial viability of small-scale crop cultivation in developing countries led to excessive economic dependence on the global food system. In many cases, vast amounts of local food are exported for economic profits and must then be replaced by import for sustenance. For instance, The Gambia exports nearly all rice produced locally and consequently is entirely dependent on rice imports (Jenkins, 2018). These inequalities in the global food value chain further fragment national markets and bring negative social and economic consequences including increasing impoverishment and food insecurity (King et al., 2017; Mc Carthy et al., 2018; J. Wilkinson, 2015).

Second, while today, 2 to 3 billion people are undernourished, deficient in micronutrients, overweight or obese (International Food Policy Research Institute (IFPRI), 2014), production of high nutritional quality food is not considered as a primary concern (Development Initiatives, 2018). The intensification of agricultural production strongly relies on the application of fertilisers, herbicides and pesticides (Erb, Gingrich, Krausmann, & Haberl, 2008), which contributes to nutrient depletion within soils, damaged ecosystem services and decreased nutritional value of cultivated food (DeFries et al., 2015; Jenkins, 2018; Sala et al., 2017). Arising agricultural methods, which reduce environmental damage, as well as diets, which minimise demands for resource-intensive foods, represent approaches to *Sustainable agricultural intensification.* However, the nutritional needs of the human diet are still not seen as priority of sustainable intensification (e.g. Bais-Moleman, Schulp, & Verburg, 2019; DeFries et al., 2015). Additionally, the purchasing patterns of developed countries are dominated by highly processed food. For instance, Poti, Mendez, Ng, & Popkin (2015) explored purchases of consumer packaged foods for 157,142 households in the United States and calculated that 61 percent of food energy in purchases by households comes from highly processed goods. This type of foods often has higher sugar, sodium and saturated fat contents compared with less processed products (Augustin et al., 2016; Poti et al., 2015). Consumption of such food and excess calories from this category is associated with the prevalence of diet-related non-communicable diseases, for instance, diabetes, metabolic disease and certain cancers (Amuna & Zotor, 2008; Wiseman, 2008; World Health Organization, 2012). Another hazard to consumers` health is caused by increasing food transit. To withstand long-distance transportation, fresh produce is treated with pesticides. For instance, in the

UK, a post-harvest chemical drench or dip is applied to 85 percent of Cox apples before storage (Paxton, 2012). Therefore, the crucial challenges for building socially and economically resilient food systems include not only progressing research, governance, financing and education on healthy diets (Dangour, Mace, & Shankar, 2017; Development Initiatives, 2018; Godfray et al., 2010; Schipanski et al., 2016; Wiseman, 2008) but improving nutritional quality of products and reducing the use of chemicals during food production and processing stages (Paxton, 2012).

1.1.1. Environmental impacts of the global food system

Many elements of the global food system contribute to climate change. The global food supply chain produces from 19 to 29 percent of total anthropogenic GHG emissions, of which agricultural production emits from 80 to 86 percent globally, while preproduction (mainly fertiliser manufacture) and the postproduction activities including processing, packaging, refrigeration, transportation, retailing, catering, domestic food management and waste disposal are responsible for the remaining GHG emissions (Fig. 63). Crop and livestock sectors are the main driving forces for forest degradation and deforestation (FAO, 2016). Each year, 1.7 million hectares of Amazonia rainforest are cut for agricultural land (Steel, 2013). The increased intensity and frequency of events associated with climate change, including heat waves, tropical cyclone events, extremely high sea levels, heavy precipitation events and associated floods, contribute to the reduction of crop and livestock production (Fig. 64), thereby endangering global food security (FAO, 2016; Vermeulen et al., 2012)

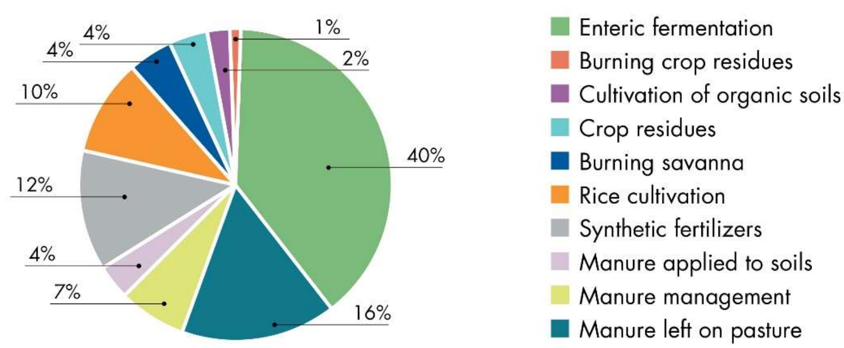


Figure 63: Shares in agricultural emission of CO_2 equivalent in 2014, by source and at the global level. Source: FAO, 2016

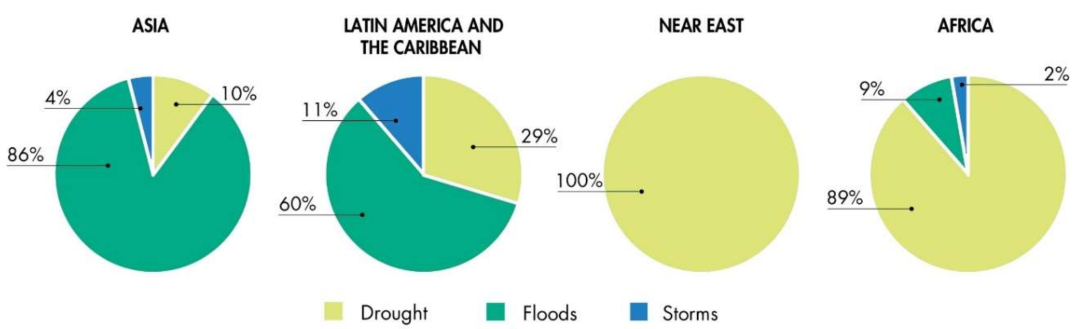


Figure 64: Crop and livestock production losses after medium- to large-scale climate-related disasters, by the type of hazard, 2003-2013. Source: FAO, 2016

The increased agricultural productivity of the global food system during the green revolution is elicited by the intensification of soil-based production achieved through involving high agricultural inputs, such as synthetic pesticides, fertilisers and mechanical energy (Erb et al., 2008). The negative environmental consequences of these methods include degradation of soil quality, impacts on biodiversity and wildlife as well as water pollution caused by leakages of pesticides and nutrients (Connor et al., 2011). Manufacturing energy-intensive fertilisers consume finite resources and contribute to the lower standard of living in the future (Jenkins, 2018).

Negative environmental impacts are associated with current food transportation patterns. Long distance trade leads to the specialisation in agriculture and the concentration of local resources on export to different regions or countries. Producers grow crops in monocultures, using varieties prioritised by food manufacturers for specific qualities, for instance, their ability to withstand longer in storage and transit. This approach leads to the continual increase of *food miles* and the reliance on fossil fuels (Paxton, 2012). The term *food mile*s, first used in the UK in the early 1990s, is based on the understanding that *the further food travels between farm and plate, the greater must be its negative environmental impact* (Kemp, Insch, Holdsworth, & Knight, 2010, p. 504). In the past twenty years, air freight of fresh agricultural products has doubled. This type of food transportation brings substantial negative environmental consequences as it is responsible for 37 times more carbon dioxide emissions compared with sea freight and due to the emission of pollutants at high altitudes (Paxton, 2012). As a result of growing food miles, the production of processed goods increased owing to their ability to withstand more extended periods in transit and storage as well as the opportunity to centralise production by transporting raw products from different regions to one factory. For instance, Böge (1995) analysed the manufacture of 150g strawberry yoghurt in south Germany and revealed that only the glass jar and milk were produced locally, while strawberries were brought from Poland, yoghurt from north Germany, jam from West Germany, wheat flour and corn from the Netherlands. Paxton (2012) estimated that to withstand long transportation distances, food is packed in four types of packaging, including primary packaging on foods, secondary packaging (e.g. boxes), transit packaging (e.g. crates), and boxes or carrier bags to carry products from shops to consumers` homes. In the UK, 1.5 billion dustbins of packaging waste are produced annually. Almost a third of this waste comes from packaging food and drink products. Reducing and reusing these packaging is constricted by growing distances between producers and consumers (Paxton, 2012).

Taken together, these environmental impacts of the global food system impose costs on the planet, which are not encompassed in the market price of food products (Jenkins, 2018; Pretty, Ball, Lang, & Morison, 2005; Tegtmeier & Duffy, 2004) and increase the environmental credit, which will contribute to the lower standard of living of future generations (Hudson & Donovan, 2014). These hidden costs call for developing and implementing innovative solutions to the challenges posed by the global food system, with the priority given to these improvements that will guarantee the future food production for the growing world population.

1.1.2. The challenges of the global food system in the face of the world`s population growth

World population is continuously growing and is projected to surpass the value of 8.500 million by 2030 and 9.700 million by 2050 (United Nations, 2015). While in 1950, 30 percent of people resided in cities, in 2018, already 55 percent of the world’s population was urban. This trend is projected to continue to achieve 68 percent by 2050 (United Nations, 2018). These facts put intense pressure on the global food system, which is expected to increase production by 70 to 100 percent by 2050 in order to meet the world`s food demand without any significant food price rises (Godfray et al., 2010; The Royal Society of London, 2009). Achieving this goal will contribute to global food security, which was defined at the 1996 FAO World Food Summit:

Food security exists when all people, at all times, have physical, [social] and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (FAO, 1996).

FAO (2014) projects that additional food required to feed the global population in 2050 needs to be cultivated on the current agricultural land. The possibility to expand the agricultural area is very limited and identified mainly in some parts of South America and Africa. In many cases, making that additional land productive is associated with high social, economic and ecological costs. Also, the consequences of climate change continuously decline crop productivity (FAO, 2016; Vermeulen et al., 2012). The reduction of agricultural yield is expected mainly in food insecure regions, particularly in Asia and Africa, where the current production is projected to reduce by 8 percent by 2050. Climate change will also contribute to the increase of the market volatility, thereby again affecting the most vulnerable people (Fig. 65) (Wheeler & von Braun, 2013).

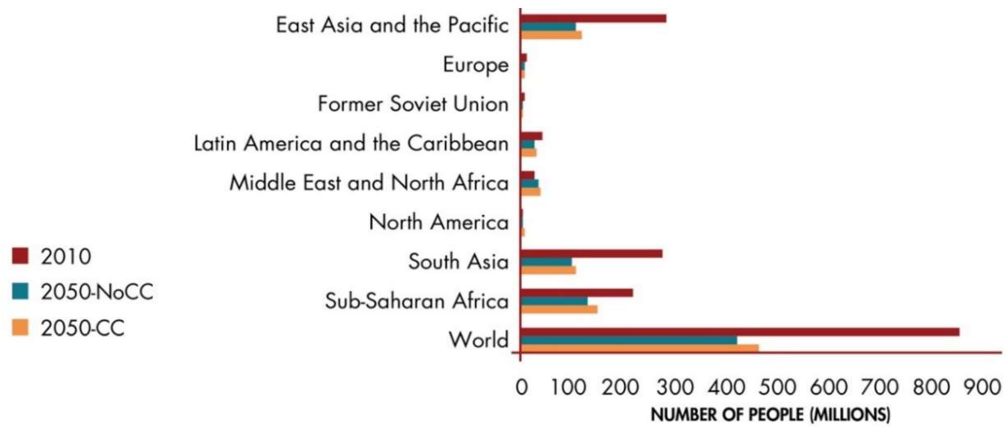


Figure 65: Impacts of climate change on the population at risk of hunger in 2050. Source: FAO, 2016

At the urban scale, agricultural production is considered as an essential function of peri-urban areas, which build the local food supply chain classified as the significant element of the global food system. Local food chains bring environmental, social and economic benefits, including the reduction of food miles and the enhancement of local economy (Paül & McKenzie, 2013; Sadler, Arku, & Gilliland, 2014; Sanyé-Mengual et al., 2016). Urban population growth as well as socio-cultural changes, including the migration of retirees to rural areas, the shift of the rural population to urban lifestyles and the transformation of business models and structures (Antrop, 2004; Bergstrom, 2001; Busck, Kristensen, Præstholm, Reenberg, & Primdahl, 2006; Zasada, 2011) contribute to the rapid urbanisation beyond former city borders and the reduction of the peri-urban agricultural land (Thomas, Frankhauser, & Biernacki, 2008). The previous research has shown that the consequences of the expansion of cities include the growing reliance on the already over-burden global food system (Paül & McKenzie, 2013; Zasada, 2011).

1.1.3. The future of the global food supply chain

The negative environmental, social and economic consequences of the global food system contest its current efficiency and future productive capacity to feed the growing world`s population. These impacts are escalated by the rapid changes in globalisation, urbanisation, human migration, growing inequities, changing dietary preferences, environmental degradation and climate change, which continuously affect global food security. As Defra stated:

The current global food security situation is a cause for deep concern. High energy prices, poor harvests, rising demand from a growing population (…) have all pushed up prices, and coupled with problems of availability, have sparked riots and instability in a number of countries around the world (DEFRA, 2008, p. 1).

In this context, many uncertainties arise regarding the future of the current food supply chain. Pretty et al. (2010) determined 14 themes crucial for the resilience of the agricultural system and based on them, defined 100 questions, which should be answered in order to enhance agriculture and food supply chain worldwide. When analysing these questions, it is prominent that despite the significant technological and scientific development over the past fifty years, the gap in the agricultural knowledge, science and technology still exists and endangers the viability of the future food supply. Therefore, further multidisciplinary and far-reaching advances are needed in order to achieve the crucial aims of the global food system:

(…) reduction of hunger and poverty, improvement of rural livelihoods and human health, and equitable, socially, environmentally and economically sustainable development (McIntyre et al., 2009, p. VI)

In this context, the global agriculture must simultaneously meet sustainability and development goals and increase agricultural production (FAO, 1996; Hudson & Donovan, 2014; Jenkins, 2018; McIntyre et al., 2009; Pretty et al., 2010). However, the significant challenge is to achieve these goals at a time when the climate becomes increasingly unpredictable, the ecosystem services and biodiversity are degraded, the competition for water from different sectors is enormous and social and economic inequities are growing globally.

2. Definitions of UA used in the literature and policy (Table 29)

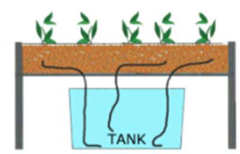
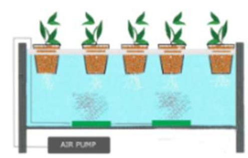
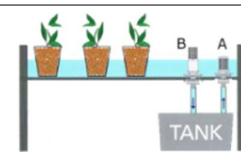
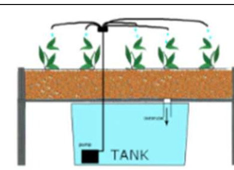
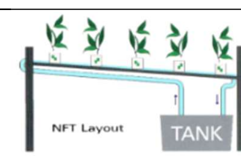
Table 29: Definitions of UA used in the literature and policy. Sources: Aerts, Dewaelheyns, & Achten, 2016; Mok et al., 2014; Mougeot, 2000; Redwood, 2009; RUAF FOUNDATION, n.d.; Thornton, 2013; Tomkins, 2014; US EPA, n.d.

Definition	Author
Urban and peri-urban agriculture (UPA) can be defined as the growing of plants and the raising of animals within and around cities. Urban and peri-urban agriculture provides food products from different types of crops (grains, root crops, vegetables, mushrooms, fruits), animals (poultry, rabbits, goats, sheep, cattle, pigs, guinea pigs, fish, etc.) as well as non-food products (e.g. aromatic and medicinal herbs, ornamental plants, tree products). UPA includes trees managed for producing fruit and fuelwood, as well as tree systems integrated and managed with crops (agroforestry) and small-scale aquaculture.	UN FAO, n.d.
Urban agriculture can be defined shortly as the growing of plants and the raising of animals within and around cities. The most striking feature of urban agriculture, which distinguishes it from rural agriculture, is that it is integrated into the urban economic and ecological system: urban agriculture is embedded in -and interacting with- the urban ecosystem. Such linkages include the use of urban residents as labourers, use of typical urban resources (like organic waste as compost and urban wastewater for irrigation), direct links with urban consumers, direct impacts on urban ecology (positive and negative), being part of the urban food system, competing for land with other urban functions, being influenced by urban policies and plans, etc.	RUAF FOUNDATION, n.d.
City and suburban agriculture takes the form of backyard, roof-top and balcony gardening, community gardening in vacant lots and parks, roadside urban fringe agriculture and livestock grazing in open space. Urban agriculture is an important source of environmental and production efficiency benefits. The use of best management practices (BMPs) and integrated farming systems protect soil fertility and stability, prevent excessive runoff, provide habitats for a widened diversity of flora and fauna, reduce the emissions of CO2, increase carbon sequestration, and reduce the incidence and severity of natural disasters such as floods and landslides.	US EPA, n.d.
UA is an industry located within (intraurban) or on the fringe (periurban) of a town, a city or a metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area.	Mougeot, 2000, p. 10, based on Smit et al. 1996
Horticultural activities within an urban or peri-urban setting, rather than animal husbandry, aquaculture, or arboriculture, since food plant cultivation is the dominant form of urban agriculture.	Mok et al., 2014, p. 22

Urban agriculture can be understood as the cultivation, processing, marketing and distribution of food, forestry and horticultural products that occur in built-up 'intra-urban' areas. the broader term, urban and peri-urban agriculture, is typically used to describe all urban food production systems, both in the built up areas and along 'peri-urban' zones or 'fringes' (also referred to as 'green- belts') of cities and towns on public, private and communal or customary land.	Thornton, 2013, p. 201
Urban agriculture (UA) is an alternative farming system based on small-scale local food production in an urban or peri-urban setting, and which often, but not necessarily, uses organic techniques and the principles of environmental sustainability.	Aerts, Dewaelheyns, & Achten, 2016, p.1
Urban Agriculture and Peri-Urban Agriculture are terms that describe the practice of growing food (vegetables, fruit, livestock and other products) within cities, to be consumed by local residents. It directly engages the urban situation as a food producing space to help eleviate the increasing unease regarding sustainable and reliable food supplies to rapidly growing global urban centres, whose population are increasingly reliant on commercial food systems	Tomkins, 2014, p. 1, based on Mougeot, 2000; Redwood, 2009

3. Five different types of hydroponic systems (Table 30)

Table 30: The five different types of hydroponic systems. Source: GrowthTechnology, 2017

SYSTEM	DESCRIPTION	SCHEME
Wick System	The system is the most simplistic hydroponic installation because it does not use electricity or pumps and does not have any moving parts. From the bottom reservoir, a specific nutrient solution is drawn up through several wicks into the growing medium. The system can use a variety of substrates, for instance, perlite or coconut fibre.	
Nutrient film technique (NFT)	NFT uses a constant flow of nutrient solution. The nutrient solution is pumped from a reservoir into a growing tray. The growing tray requires no growing medium. The roots draw up nutrients from the flowing solution. The downward flow pours back into the reservoir to be recycled again. Pump and electric maintenance are essential to avoid system failures and, where roots can dry rapidly when the flow stops.	
Water culture or deep water culture (DWC)	The system is an active system with moving parts. The roots of plants are immersed in water, which contains a nutrient solution. An air pump helps to oxygenate the water and allow the roots to breathe.	
Drip system (recovery or non-recover)	A system where a timer controls a water pump, which pumps water together with a nutrient solution through a network of elevated water jets. A recovery system collects excess nutrient solution back into the reservoir. A non-recovery drip system avoids this allowing the pH of the reservoir not to vary.	
Ebb and flow system	The system works by temporarily flooding the grow tray. The nutrient solution from a reservoir surrounds the roots before draining back. This action is usually automated with a water pump on a timer.	

4. Comparative Life Cycle Assessment (LCA) of renovation and demolition followed by new build

LCA is a method which developed within the last 20 years, and evolved into the ISO-14040-44 standards. Standards for presentation of results arising from LCAs have been adapted as Environmental Product Declarations or Type III declarations. They include the life-cycle stages of all products, including building products and construction (ISO 21930 and CEN TC350). ISO 15686 *Buildings and constructed assets – Service life cycle planning* has been specified to complement ISO14000 by informing how environmental standards can be utilised in building projects (Sharma, Saxena, Sethi, Shree, & Varun, 2011). Applying a LCA before making architectural decisions is now widely practiced, and includes considerations on the future scenarios for urban structures (Schwartz et al., 2018; Vilches et al., 2017).

There is a relatively small body of literature that compares benefits arising from the adaptive reuse of a building with those from demolition and new build using LCA. During the review of these studies, no research focused on multi-storey garages was identified. However, the analysis revealed the emergence of several central themes, which may lead to the decision to up-cycle an existing building instead of replacing it.

First, adaptive reuse brings significant environmental savings compared to demolition and new build (Berg & Fuglseth, 2018; Bull et al., 2014; Gaspar & Santos, 2015; Hasik et al., 2019; Schwartz et al., 2018; Vandenbroucke et al., 2015; Vilches et al., 2017). Assefa & Ambler (2017) conducted a comparative LCA for evaluating the environmental impacts of repurposing a library tower, and demolition options followed by new construction. When deciding for up-cycling after selective deconstruction, instead of demolition and new construction, a potential environmental impact reduction, between 20 and 41 percent, was achieved in six out of the seven environmental categories investigated. The highest decrease was associated with the Eutrophication Potential, followed by a 37 percent reduction of Smog Potential. The lowest reduction, at 20 percent, was for Human Health Criteria. The impact avoided in two closely correlated categories, Fossil Fuel Consumption and Global Warming Potential, was 34 and 33 percent respectively. In a similar vein, a significantly lower environmental burden has been reported as an outcome of the comparative LCA of two scenarios – refurbishment, and demolition and new build - for the student hall of the Vrije Universiteit Brussel constructed in 1973 (Vandenbroucke et al., 2015). The negative impacts of demolishing the structure, especially its foundations, and developing a new structure, affect the conclusion that the environmental benefits of repurposing the building remain significant from a long-term perspective.

Second, the selection of material for up-cycling a structure strongly affects the outcome of a comparative LCA of retrofitting versus demolition followed by new build (Berg & Fuglseth, 2018; Gaspar & Santos, 2015; Schwartz et al., 2018). This is because the energy content of all of the material used in the building counts in the embodied energy of that structure. Embodied energy is *the energy utilized during manufacturing phase of the building* (Ramesh, Prakash, & Shukla, 2010, p. 1593). A detailed exploration of 73 office and residential case study buildings located in 13 countries conducted by Ramesh, Prakash, & Shukla (2010) revealed that embodied energy accounted for 10 to 20 percent of building life-cycle energy use. If the material used has a shorter life span than a building, it is replaced in the process of rehabilitation or regular maintenance. The energy content of these processes adds to the embodied energy and creates recurring embodied energy. When the building is demolished, energy is needed to conduct that process and transport the material as waste to landfill sites or recycling plants. The energy used in that phase is termed demolition energy (Ramesh et al., 2010). Previous research has established that the utilisation of recycled materials from construction and demolition causes lower environmental impacts than using equivalent materials manufactured from virgin materials (Assefa & Ambler, 2017; Berg & Fuglseth, 2018; Bovea & Powell, 2016; Gaspar & Santos, 2015; Knoeri et al., 2013; Lawania et al., 2015; Ramesh et al., 2010; Simion et al., 2013). These findings are crucial when considering the future scenario for multi-storey car parking structures, because concrete and steel, two materials mainly used for the construction of these garages in the modern movement era, generate significant environmental impacts. Therefore, a comparative LCA of the two future scenarios: adaptive reuse or demolition and new build, would indicate very high levels of embodied energy, and potentially demolition energy, for a multi-storey structure.

Third, data from several sources highlighted the significant role of energy retrofitting (Ghisellini et al., 2018; Vandenbroucke et al., 2015; Vilches et al., 2017), which reduces environmental performance in the use stage of the building from the life-cycle perspective. Ramesh et al. (2010) evaluated that operational energy accounted for 80 to 90 percent of the building's life-cycle energy use. Energy retrofitting actions can be done through relatively simple measures, including insulation improvements, air-tightness or ventilation control (Buyle, Braet, & Audenaert, 2013). Further opportunities are identified when implementing alternative energy technology options and energy-saving technologies (Buyle et al., 2013; Schwartz et al., 2018; Vandenbroucke et al., 2015). The International Energy Agency (2001) assumes that the average lifetime operating efficiency of buildings with features that provide opportunities for integrating innovative, efficient technologies increases by 10 percent or more. However, the excessive use of these measures may have adverse outcomes on the LCA due to their increased embodied energy (Ramesh et al., 2010). A review of existing studies on the environmental evaluation of building renovation and refurbishment using the LCA methodology conducted by Vilches et al. (2017) indicated that energy retrofit included in the up-cycling process is beneficial from an environmental point of view when the extended life of the building is longer than the payback period (Vilches et al., 2017).

Considering all of this evidence, it seems that there may be good reasons for both scenarios revealed by Henley (2007) for the future of modern movement car parking structures. As the present research studies, for the first time, the adaptive reuse potential of modern movement car parking structures for CEA from an architect's perspective, it focuses on the initial design phase. It is necessary to explore the opportunities and limitations for such a retrofit to develop an initial design scenario which would create a foundation for analysing whether this architectural type may gain significance regardless of its primary use. The data and findings generated should support further studies into the comparative LCA of the proposed up-cycling compared to demolition and new build, which is beyond the boundary of this thesis.

APPENDIX B Supplementary data for Chapter 4

This appendix plays a supplementary role for data collected in Chapter 4.

1. Properties of cladding materials for RTGs (Table 31, 32)

Table 31: Evaluation of the appropriateness of materials to be employed in rooftop greenhouse, main advantages and limitations. Source: Montero et al., 2017

	MATERIAL	APPROPRIATE	ADVANTAGES	LIMITATIONS
1	Glass	Yes	Good light transmittance; Good heat retention (i.e., particularly at night); Low transmission of UV light; Durability (long lifespan); Low maintenance costs	Needs to be hail-resistant (hardened glass, also for labour safety); Higher costs of the structure; Higher weight
2	Semi-rigid plastics			
	Polycarbonate (PC)	Yes	Good light transmittance; Lightweight; Fire-law-compliant; Impact resistance; Hail resistance	Lifespan 10 years- it becomes brittle; Ageing reduces transmission long before then; Maintanace requirements, Algae formation in cells
	Polymethacrylate (PMMA)	Side walls only. Under fire, it melts and drips	Good light transmittance; UV filter (300 nm); Strong and lightweight; High corrosion resistance	Poor resistance to chemicals; Higher fragility than PC; Lifespan: up to 30 years; Fairly low hail resistance
3	Plastic films			
	Polyvinylchloride (PCV)	Yes	Strong and lightweight; High resistance; Does not propagate the flame	Lifespan 10 years- it becomes brittle (20 % transmittance loss); Environmental toxicity
	PE-based films (multilayer)	Side walls only. Under fire, it melts and drips	Law-compliant only for walls; Strong and lightweight; High resistance; Cheap	Maintenance (change) is required every 3-4 years; Additivities for complying fire safety laws can be added (e.g. fire-retardant)
	Ethylene Tetrafluoroethylene Copolymer (ETFE)	Yes	Fire-law compliant; Long lifespan; Lightweight; UV filter; High corrosion resistance; High melting temperature; Flexible; High light transmittance	High costs (expensive)

Table 32: The key thermal properties of commonly used greenhouse covering materials. Source: Ahamed et al., 2018b

COVERING MATERIAL	Number of layers	Solar radiation transmission (%)	Long-wave radiation transmission (%)	Emissivity coefficient	Thermal conductivity ($W\ m^{-1}\ K^{-1}$)	Infiltration rate (ACH)
Glass (3.2 mm)	Single	88-93	3	0.9	0.76	1.1
Low emissivity glass (3.2 mm)	Single	78	<3	0.3	0.76	1.1
Diffusive glass (3.2 mm)	Single	8-85	<3	-	-	1.1

Polyethylene film (6-8 mil, UV-stabiliser)	Single	87	50	0.2	0.33	0.85
	Double	78	<50			0.75
Polyethylene film (6-8 mil, IR-barrier)	Single	87	20	0.2	0.33	0.85
	Double	78	<20			0.75
Poly-carbonate panel (6-8 mm)	Single	90	<3	0.79	0.17	1.1
	Double	78-82	<3			0.85
Acrylic panel (8 mm)	Single	90	<5	-	0.2	1.1
	Double	84	<3			0.85

2. Architectural strategies to implement BIWT

The research on the BIWT systems is mainly focused on high-rise buildings where they can be applied in three ways. First, one or more large-size wind turbines can be installed on the rooftop, between two adjacent buildings or inside a hole in an architectural structure designed for this purpose (Fig. 66). This technology has already been developed in full-scale buildings, for instance, the Pearl River Tower in Guangzhou and the World Trade Center in Bahrain. However, despite their high efficiency, several critical problems have been reported, including vibration and noise issues and aesthetic dissatisfaction (*Urban aerodynamics. [electronic resource] : wind engineering for urban planners and designers.*, 2011). The implementation of these types of wind turbines in existing buildings requires specific structural strengthening and modifications as the wind turbines are subjected to wind loads. Additionally, specific decisions should be made on the planning and design stage in order to concentrate wind flows on that urban zone where turbines are installed (Park et al., 2015).

The second strategy to implement BIWTs is to position many small-size wind turbines on the external skin of a building as shown in Fig. 67. This method is seen as more economical than the application of large-size wind turbines and in the case of existing buildings, it may not require structural strengthening. However, the energy produced by this BIWT system is lower than that from the first strategy due to the limited installable areas to edges of buildings and rooftops (Park et al., 2015).

The third method is to directly utilise the skin of a building or an exterior wall which is a large, unused area subjected to wind pressure. Park et al. (2015) developed a prototype of such a system consisting of a guide vane, which effectively collects the wind and increases its speed and a rotor. The comparison of energy potentially produced by this wind power technology with the energy consumed by a residential building revealed that the proposed system would supplement about 6.3 percent of the required electricity. Importantly, this technology can be applied to existing architecture without structural modifications. Before selecting the application method of the wind power system, the analysis of the specific urban context and urban aerodynamics needs to be conducted (Hartman, 2001; Ishugah, Li, Wang, & Kiplagat, 2014; Park et al., 2015; Stathopoulos et al., 2018).

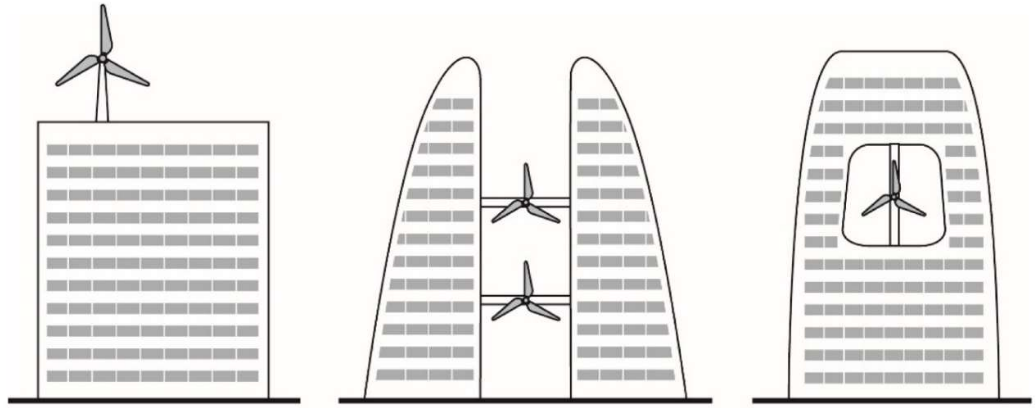


Figure 66: Building-integrated wind turbine system using wind turbines: three possible installation locations of large-size wind turbines. Source: Park et al., 2015

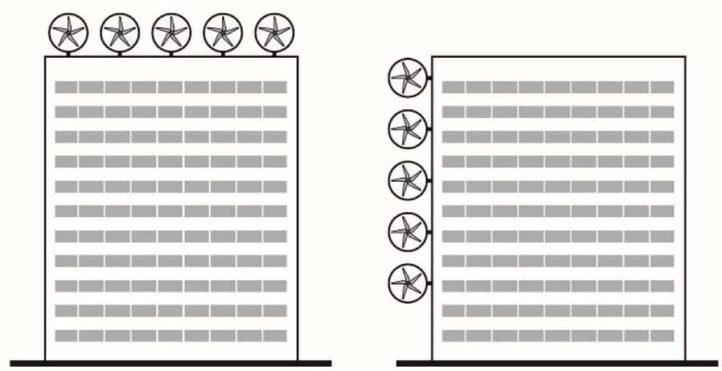


Figure 67: Building-integrated wind turbine system using wind turbines: two possible installation locations of small-size wind turbines. Source: Park et al., 2015

APPENDIX C Supplementary data for Chapter 5

This appendix plays a supplementary role for Chapter 5: Interviews with practitioners by presenting the questionnaire and transcripts of interviews.

Table 33: Questionnaire of the interviews with experts

Thematic category	Questions
Planning	1. Is the adaptive reuse of the inner-city multi-storey car parking structures a familiar and acceptable concept within the professional domain? Would you think of this as a permaner temporary use?
	2. What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car parking structures for CEA?
	3. What are the key planning limitations for the adaptive reuse of inner-city multi-storey ca structures for CEA?
	4. Which strategy should be applied during the adaptive reuse of inner-city car parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?
Architecture	1. Do you consider multi-storey car parking structures from the modern movement era as an architectural value in inner-cities?
	2. What are the key architectural opportunities for the adaptive reuse of the inner-city multi-storey car parking structure for CEA installations?
	3. What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car parking structure for CEA installations?
	4. Which architectural modifications should be applied during the design process of the adaptive reuse of inner-city car parking structures for CEA in order to address the opportunities and limitations of such an up-cycling?
Environment	1. Would you consider the adaptive reuse of the inner-city multi-storey car parking structure as a value in terms of environmental sustainability?
	2. What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car parking structure for CEA installations?
	3. What are the key environmental limitations for the adaptive reuse of the inner-city multi-storey car parking structure for CEA installations?
	4. Which technologies should be implemented in the process of adaptive reuse of inner-city car parking structures in order to minimise the use of urban resources (water and energy) and produce energy by alternative technology options?

Interviews with practitioners

Interview 1

Interviewer: Is the up-cycling of inner-city buildings for urban farming a familiar and acceptable concept within the professional domain?

Interviewee 1: No, it is not. It is for me because I always worked as an architect on the circular economy and cradle-to-cradle. I am a cradle-to-cradle accredited architect, one of the three in the world. It shows why it is so important to up-cycle buildings. There is obviously more buildings to be up-cycled than new buildings to be built in the world. If you take particularly the once that have a large area, more industrial buildings or large office buildings, shopping centres and that sort of things, there is a lot to do. It is not something that is common in the profession. Architects and developers tend to knock down and build something new when they can. And today I tend to try to prove that it is possible to have a viable and economical solution to up-cycle buildings.

Interviewer: Would you think about the adaptive reuse of inner-city car parks for urban farming as a permanent or temporary use?

Interviewee 1: For me, it has to be permanent. It depends on what you call permanent. I am working on a temporary project, but it is temporary for 25 years. It takes at least 5 to 6 years to pay back the investment. And you can only do that if you spread the costs over a long time. So you need to spread the amortisation over 25 years so then what you pay for a year is reasonable. For me an urban-industrial way of producing food, which is what we are doing here, we are a small industry, very small comparing to large but the big industry about what people call urban farming like the external gardens on the roof, they do not make money and they never payback. They have other advantages. So what I am trying to do and we are really trying because we are working on a system that seems to be viable but you can always have accidents when you work with plants. So it is not easy to make it profitable. We think we have a system that can be and it will certainly be when we make it bigger. Which means greenhouses that are 4000 to 6000 sqm, then they really become interesting. The size which we have here is 2000 sqm of greenhouse and fish system and then 2000 sqm of roof gardens are on the low limit of size so we need an economy of scale to make it work.

Interviewer: What are the key architectural limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA in Portsmouth/Bristol/Brighton & Hove?

Interviewee 1: The first thing is the size of the roof or size of the land next to the building. The second thing, if the farm is on the building, is the weight limitation. For the greenhouse, you need at least 300 kilos per square meter of load that the roof can take. This is a case for most flat roofs if you take a shopping centre or a hangar or a logistic building it usually takes 100 to 150 kg, so we need about twice as much. And the fish system needs about 1000 and 12000 kg/sqm, so the limitation is physical. But that is easy to calculate and to estimate the costs for reinforcing if it needs reinforcing. Also, the fish system can be put on the ground and the greenhouse on the top. That is what we try to for our next project. It is not cheap to be done because when you put the fish system, in our case we have 200 cubic meters of water, that is 200 tones on the roof and that is quite difficult to set on most of the buildings. We are happy that we have a building here that have a strong roof because it was planned to do some kind of urban agriculture, they didn`t know what it was so they reinforced it more than necessary. The greenhouse is not heavier, it should take the load on the slab, it is not heavier than a productive garden, where you need a 30 cm of a substrate. You only have a structure of the greenhouse which can be designed to have exactly vertical to the structure of the building so the building needs to carry up to 10 t and it also needs to resist the wind up to 3t. So it needs to be a fixed structure.

The next thing is access. You need access to logistics- it is not very heavy. They only need access at the bottom of the building with a van. You need to have a lift- good lifts able to carry about two tons to carry all the loads to bring in and out.

Fire regulations can be a limitation. Depending on the use of the building underneath, the fire brigade they tend to insist on having fire protection for the structure of the building and it is impossible to have fire protection for the greenhouse. It has to have a special status of a greenhouse or a productive space which derogates the rules of construction in general in the cities. What we found also and we manage to fight for that in Brussels and in Belgium in general but also in France, Paris is to make sure that the area of the greenhouse is not taken into account as if it was office space or retail or residential. Otherwise, you cannot compete with the use which makes a lot more money. So the idea to use the roof that is unproductive and does not create a rent most efficiently. Here you can see solar panels, the PV panels which are not in our greenhouse, they are in the next building. You can combine photovoltaic in the glass of the greenhouse itself because they tend to have so much sun and light.

You need to be in an area where you can distribute in short roots so to have a short distribution channel. The whole idea of urban agriculture, even if it comes to the size where you make tonnes of tomatoes is to sell it locally. The value is to reduce the need for mobility, so it doesn`t make sense if you sell a product, but you need a lorry to transport it 50 km away and when you need a freezer and then the product comes back in a freezer three days later to the local shops. So you need to have direct distribution and this is not easy. In all the things, this one is the most difficult to organise is the right logistics because you need to distribute two, three times a week, to 15 to 20 different shops or restaurants.

We use mainly a van or a car because for example a fish cannot be distributed by a bike. So we are looking for partners here in Brussels, also at the university, is to find partners maybe startups, that are really adapted to the city logistics but are not too expensive otherwise you loose ale the bargain from the product you are selling.

So a further market study is essential, for instance, you have seen that here we have a market, but I cannot sell here because the average prices are far too low for the hydroponic production that we have. On this market, local people are selling tomatoes for 1 Euro per kg. We sell at least for 12 Euro per 1 kg of tomato which is entirely different; it is not the same product. We sell products that are on the high end of the middle of the market.

Interviewer: So who are mainly your clients? Shops? Restaurants?

Interviewee 1: We sell a lot to Cafo. It is a grocery that has the policy to buy from local producers, so we sell in these large shops like hypermarkets. Our products are delivered directly to the shop so it doesn't go through the typical logistic chain. So that`s quite a big quantity. And then we have a big number of groceries and luxury shops, restaurants and catering. People are waiting for local products.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 1: Ideally, you need to transform what you grow. You should cook it, for instance, if you grow fish you should then sell it as a smoked fish, raw fish, fillets, fish muss so to create different products. And this is what the other value is and this is what we are also interested in. Ideally would be to have the same location for growing, transforming and selling and then consuming in restaurants or using the nearby market which should be a quality market. And then you would have a very nice mix to make it work. Because then it is a win-win to everyone. So we are working on concepts like that. Look at Mercato Metropolitano, the concept that exists in London. We are working on several new concepts together to combine a market, a restaurant, an organic shop and a space for events also. There is always something happening and this is something that allows us to sell our products locally- it is that many people come here.

Interviewer: Would you consider the adaptive reuse of the inner-city multi-storey car-parking structures as a value in terms of environmental sustainability?

Interviewee 1: Definitely a value. Three years ago nobody knew what aquaponic was. Today everybody knows that this is a mix between aquaculture and hydroponics. It is what we do here. Aquaponics is quite difficult to make it work. You have to remember that you want to sell it to people as food and you are expected to comply al the sanitary regulations. If you want to produce all the year-round, it depends in which climate, but you need to have access to energy, like the heat, we have a butcher shop beneath the building here and there is 1000 sqm of cold rooms which are working all the time and we take their heat for the production of cod- for heating our water and our greenhouse so we are about 60% autonomous in the energy supply so we would like to go to a hundred % one day that will happen probably during our next project. So all that is quite technical. But if you want to produce on a regular basis quality products that are or a less the same price all year long because that is what everybody wants it needs technology, it needs control and it needs exchange with the building.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 1: First, we have a closed-loop system which is called RIS which is a recirculating aquaculture system. It is basically using the same water all the time, apart from 5% which we extract to feed the plants and that is 5% per day. It is a closed-loop were the fish water is cleaned twice per hour. Totally we have 200 quick meters, so we have about 400 cubic meters cleaned by a biofilter. A biofilter is a big swimming pool with billions of bacteria which transforms ammonium from fish pee to nutrients for plants, especially tomatoes. The fish live in a totally natural environment, without chemicals, antibiotics, you cannot use antibiotics because it would kill the biofilter- the antibiotics would kill the bacteria that are cleaning the water. So this is the transparency of the system. And the next step is to clean the water in the biofilter and 5% of this water goes to feed the plants so it is not wasted because it goes to the plants. So in that sense, we are zero-waste. The plants themselves are in the closed-loop again. Where the water is circulating and coming back to the plants until it is all evaporated by the plants. So in theory, it depends on the plants but generally, we use all the water that we take and the water that we take is from rainwater. We harvest the water on the roof of the greenhouse and from well water. We have a well that is 70 meters deep. We also exchange energy with the butcher's factory located in the same building under the farm. They need cold and we need heat. It costs twice as much energy and twice as much money to make cold than to make heat so it is a win-win situation because we collect heat from PV cells and they are getting cold for their fridges so it is a real symbiosis with a building.

Interviewer: Which technologies should be implemented in the process of adaptive reuse of inner-city car-parking structures in order to minimise the use of urban resources (water and energy) and produce energy by alternative technology options?

Interviewee 1: I have plenty of ideas. I want to combine this with pure cells that are working on natural gas. Because pure cells usually are working with hydrogel, which is not produced naturally, so if you use a pure cell on natural gas it creates electricity, heat, it creates pure CO2 which I need for my plants because plant for the photosynthesis they need a higher version of CO2 in a greenhouse so that they can grow faster and better. And it produces clean water. That would also produce more electricity so I could produce electricity for other buildings around us. There are plenty of other ideas, but I need to test them first. My idea is to be zero waste and completely autonomous regarding energy and water.

Interviewer: On your website, I read: Building + Agriculture+ Cradle-to-cradle circular economy. Do you consider this as another opportunity for environmental sustainability enhancement?

Interviewee 1: Yes, nobody is perfect and no project will be a hundred percent. But we are doing a lot better than the others are doing anyway by following these principles. So in some cases, you may have not enough heat or CO_2 or you do not have proper access so all that are compromises, especially when you talk about the existing buildings, you have to work with what you have and it is not always easy.

Interviewer: Let us focus again on the car parking structures. What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 1: Most of these car parks can take a greenhouse. If you have a spread car park with half levels, you usually have three columns in the middle and then one column in each end and when you manage to remove some of the weight of the existing car park, let us say the top level. You can use these three columns which are very close together to be able to put the aquaculture part on it. Ideally would be to put aquaculture on the bottom of the car park and put a greenhouse on top. The fish do not need sunlight, they need a regular light and it needs to be quite well insulated and well protected from the external environment. So you should use most of the surface of the area of the car park above to install a greenhouse. The greenhouse systems are 300 kg and most car parks can lift between 250 and 400 kg so it should be ok. And very often in 60 and 70ies things were over-dimensioned so, in general, the foundations are already settled and you can add weight on them as well. So it is even better than a new car park sometimes.

Interviewer: Which architectural modifications should be applied during the design process of the adaptive reuse of inner-city car-parking structures for CEA in order to address the opportunities and limitations of such an up-cycling?

Interviewee 1: You have a car park- you have access. You have ramps. In general, they cannot take vans, but they can take cars and other small vehicles which you could use to transport all the goods you need. Alternatively, you can have a flock lift going up and down. 2 tons of goods lift is better because that is the shortest way between the top and the bottom of the car park. You should have a lift because it is difficult to carry plants in pots, eg., aromatic herbs using a ramp. So the lift is essential. Visibility is good and when this car park would be used to sell products, it is even better. So maybe you could use one part of the car park for a driving system where people can come by bicycle or by car and collect the boxes with the food they ordered on the internet and go away, so you do not need much transportation. You need a space where people can stop and collect their veg boxes. For the rest, you need to be careful when you have visits because it is almost a touristic attraction. So you have to be careful with the fire brigade rules, so maybe you need to add a staircase for the escape.

It depends on carparks if you can collect the heat from somewhere, or maybe you produce on your electricity, water, CO2 which you could use for your farm so your car park would become energy production as well as food production.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA?

Interviewee 1: Every city wants to have greenhouses in their city. I have demands every day. Sometimes people are saying that cities are polluted, but when you compare urban pollution with rural pollution where pesticides are used, it appears that cities are not so polluted. And it will be less and less polluted by the time when we will solve mobility and clean vehicles. Don`t forget that bees live better in cities than in the countryside now, so it is proof that the city is an excellent place to cultivate vegs. Also, cities have a slightly higher level of CO2 in the atmosphere which is suitable for the plants and you don`t have pesticides. Because the worst thing in agriculture is the presence of pesticides and it is very difficult to get rid of them in the countryside. Urban agriculture is not going to replace urban agriculture. It is just participating and showing a way, but we need to see improvement in agriculture in general.

Interview 2

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 2: The first thing structural limitations of the building. When we arrived at the Irwell House it was in a very poor state and we wanted to add a lot of weight to that building that was falling apart, that was subsided in the middle, had issues with watering, cracking, windows and it was bearly standing up. Now your research is looking at car parks which are far more resilient than our building. So that was a limitation for us, but it probably will not be such a significant limitation for you.

The second limitation is I would say, is the access to the natural light. So if you are growing in buildings and not upon them, you are restricted in the use of natural light, which mean you become reliant on artificial lighting, which is a less efficient way of growing crops currently. So in my current research, which I have been doing since I have published my PhD, I have come to learn that vertical systems, so indoor vertical systems that are artificially lit can be or are 5 times less efficient than growing food in a traditionally lit greenhouse. So that is another key constraint and another thing that should be included in your thesis if you plan to use artificial lighting is the energy concern, so how much energy is going to the food production in a car-parking structure and can this energy be delivered by any sustainable technologies and preferably, install within the car park itself to utilise it for growing food.

The third limitation is about understanding the distribution of the food when it is grown. So we could grow a million lettuces and if we have got nowhere to sell them, they just rot. And all the energy that has been used to grow that food would have been wasted so that always need to be considered when we are talking about the urban food system.

Interviewer: So have you sold the food from the farm?

Interviewee 2: Yes, there was a little shop which was set up during the Manchester International Festival in 2013, which was called 78 steps because it from the front door of the Irwell House to the front door of the shop that was just on the other side of the road so instead of talking about food miles we were talking about the food steps. The food was sold to the local community; there was food sold during the festival and after the festival. But the number of people buying food after the festival was obviously less. The economic viability of urban food system is in the hands of well-established farms across the world that are going into administration and because it is still a new industry they are still learning what the perfect economic model is. So the shop that we were selling the food through did not last that long because the market was not there to buy that food. But the farm was included in the veg box distribution as well, so that was another way of distributing the food.

Interviewer: So when you left the project who led it after you?

Interviewee 2: So we were there for about 10 months, I think. We handed over the system to Biospheric Foundation and the production of a technical manual administered that, so the description of how to run the system, all the technical drawings and a key part of that was the maintenance schedule so how to look after the fish and crops and we had chickens on the roof so how to look after the chickens. So we produced the manual and then we had a series of training sessions one to one with the man called Ben who was going to be taking over it and he sings on the form that he understood what he has been thought and anything that he did not know it was agreed to contact us with any questions. We were very interested in the design and a kind of architectural significance of it.

Interviewer: Do you consider multi-storey car-parking structures from the modern movement era as an architectural value in inner-cities?

Interviewee 2: I would say they definitely represent value and I advise to use existing buildings because I would expect that the embodied energy of building a new building was so high that you would never be able to justify it by local food production. You know, the embodied energy of all the concrete, steel and the demolition of the existing building. Also, the economic viability of that is the main reason why it has not been done yet. Unless someone is willing to spend a lot of money expecting to make a loss purely to experiment with that as a method of food production and I do not expect that to happen. So economically thinking it would never work. And the aspect of the embodied energy for the demolition and then building a new building and then for running the farm and if it is an indoor system then it would be high anyway, so I would say that we should definitely be growing food within and upon existing buildings. If they are empty, they are right to use in any way people want to use them, so urban food production is an excellent way of using existing structures. And it puts that food production exactly where it is needed which is inside the city.

Interviewer: What are the key architectural opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 2: I am a big advocate of naturally lid systems because they use a lot less energy and they require not as much artificial lighting. So in terms of urbanism and naturally lid systems I think urban food production can add a lot to a city because it reintroduces ecosystem services to the urban environments and makes it green places to live. It increases the ecological base of the city, which can improve air and water quality. It can improve the quality of the spaces that we can interact with. There is a lot of research about how nature can improve the well-being of people; I would argue that the visual connection with agriculture brings similar benefits where instead of seeing concrete and glass and steel all of that but clad in greenery, which makes the city a nicer place to be.

Socially as well it allows for public engagement, community engagement, job creation.

Architecturally, it gives us an opportunity to improve the places where we live and work. There is a lot of research done showing that there is a lot of workplaces where we do not work efficiently because we feel poorly and it negatively affects us. So this is a benefit to have buildings that are green externally or green also internally. This can have a positive effect on people who work around that building as well as on those engaged on it on a personal level.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA in Portsmouth/Bristol/Brighton & Hove?

Interviewee 2: Probably food distribution would be probably one of the best once. When you have food production together with the point where it can be sold that is a very good way to sell some of your product. Another thing that would be very supporting is producing all the energy that you require either for the artificial lid or naturally lid. The biospheric system it only needed only 2kgW of energy and that was for the three pumps that we had and for the monitoring system. We were at the position at that time where we did not have a PVs although there was a space left for them on a roof which was planned but never happened. Our system, we managed to build it for 28 000 pounds, so it was like no money at all. But we did not have any funds to purchase a photovoltaic system. But if you are producing all the energy that your system requires and then you have a point of distribution at a ground level for the sale of that product than the system is much more resilient.

Interviewer: What about water harvesting? Have you captured the water for the aquaponic system?

Interviewee 2: We did not harvest the water but we have spoken with aquaculturist about the development of the system and we were told that we could use greywater. It just needs to be pumped through an activated cabin filter and it probably needs to be much more sophisticated than our filter.

Interviewer: What are the other key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 2: I think that is all because you need electricity and you need water. One thing why we have chosen aquaponic system rather than hydroponics is that it creates an ecosystem that is self-regulating and which is slightly different from hydroponics which needs a little bit more human intervention and managing the number of nutrients that are in the water. In hydroponics, you add nutrients, but there is no evidence telling in an economically viable way which nutrients have been taken and which have not. So the water use of the system is generally a little bit higher than in an aquaponic system. In the aquaponic system, you add water and then you nurture the water, you keep it in a system and you only need to top up in terms of evaporation and transpiration and small drips and leaks that you have across the system.

The aquaponic system also enables to engage in a circular economy. So one example of that is taking waste cardboard and paper and green waste from the city and using that to grow worms that can be fed to the fish. So you engage that waste streams from the city that would otherwise go to the landfill more than likely or would use a lot of energy to recycle. Hydroponics cannot do that because you are relying on human-made fertilisers, which are not very environmentally friendly for example in terms of mining phosphate.

Interviewer: Did you have any food processing facilities there?

Interviewee 2: Well we did not have any facilities for food processing. We have only harvested one crop of fish from the system. The restaurant that purchased the fish harvested them by themselves.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA in Portsmouth/Bristol/Brighton & Hove?

Interviewee 2: It was not only about the research but also about social benefits. The Queens University Belfast was there; we were designing the system. In order to facilitate this, we engaged a lot of local experts, agriculturalists, Botanics and people like that, who were willing to give their time for free. So actually the group of people that we needed as well as all the structural engineers that we engaged with and the Manchester International Festival themselves, so the team that developed the system was quite large anyway.

On the social side, although we designed it, we needed a lot of people to help us build it and a large proportion of people were people from the local community. So people volunteered through the festival and then they became official volunteers. We also had people from the local community who came to help or just knock on the door and we said come and help us because there was always so much to do. What we found was that the community engagement was increased through the construction of the system and the operation of it. Three tower blocks were near it. And there were people who live next door to each other and they never met but by being involved in Biospheric Project they met each other and the social cohesion of these was improved as a result of us being there. One thing that we found is that people who live in these tower blocks did not have any common space that gives something to their community that they can be proud of, that they were proud of and something that they can look after. So the social benefits of our farm were massive. During the festival, I think there were 30 classes of school children.

In the UK we have an ageing farming population. In the traditional way, it was that the siblings were taking over the farm from the parents when they got older. As education improved and the income increased elsewhere, young adults are less inclined to take over the farm from their parents. Urban agriculture is a way of making kids interested in agriculture again. A good thing to be a young urban farmer is that you can be a farmer during the day and in the night you can go out to a bar and meet up all your friends and you are not in a field that is far away from the city.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 2: It can be a mixed-use building. There is a company who contacted me and they are looking at alternative uses for car parks, such as parking for electric vehicles or autonomous cars in the future. Another thing they were looking at is local servers for banks for example. I am not really convinced about the servers, but one thing you have from that is the heat so you could utilize the heat from the servers to be able to heat your farm. Another thing that they were looking at was logistics. That is not exactly my opinions but the things that they are looking at.

In my opinion, you could mix the farm with the tech startups so you would have a collaborative working space for different industries. Another thing is to have your own point of sale that is a part of the farm, or you could work with existing supermarkets. The one thing that you need to do is to separate the farm from the rest of the building because you need to control parameters like the humidity and temperature and few more. You can also have a café and bar on the top floor. So this is also very nice to have spaces that can improve local community cohesion. When you have some kind of social spaces in the building, it can generate greater rental prices within the building. And the rental market is getting so aggressive that the owners are looking at some kind of facilities that

Interview 3

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 3: I think sit is already. High-density cities where the growth areas are far away from where the city itself consumes a lot of resources, they can benefit from higher density food production. It relaxes the pressure slightly that that city puts on the rural environment so it internalises what would normally be externalised. Other cities, cities like Bristol, I think they will want it in the future. So this is a justification for doing this work now. If you buy pach-choi, tomatoes, cucumber in the supermarket now there is a good chance it is produced using hydroponics, but it is probably produced in the east of England or Holland or Spain. So we are importing hydroponic products that are grown on a landscape far away. And all of the environmental costs of that, of transport are very high. So this is a kind of interesting that this is already normal to eat this food. It is just not normal to grow it. Putting urban farming into a city, it is bringing the food production in front of consumers face. So, that may make people think that it is more important to make food nutritious than to make it pretty. And most companies that work on intensive hydroponics do not think about nutrition. So what are you buying? The image of the salad? It is like a sculpture. So getting people to know that this future technology is and to make them realise that that may be for them and for they profit if they want to take some ownership of it is essential.

For the first time in history, we are not tight to the geography of our food. We can grow meat in a lab. We can produce food in the warehouse. We can create our environment and that will be very important for this type of technology because we are not making food for people who can make food easily. We are making food for people who cannot make their own food very easily. So it is not for people with allotments.

I know quite a lot of people who use hydroponics and aquaponics on a small scale at home because they do not have an allotment. Because they cannot have access to a garden and maybe that is also that question: if you do not have good land, this gives you the opportunity to grow food, so it is interesting.

The good think about the car parks is they are the same, most of the are identical, so you have an opportunity to check your concept and then, when you are correct you could multiple your concept. I think that the landscape for investing in agri-tech will expand. Like it has in America, which is not seen yet in Britain. And when it happens, this kind of projects will get the funding which they deserve.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA in Portsmouth/Bristol/Brighton & Hove?

Interviewee 3: We have some strange planning laws in Bristol. You are still allowed do keep livestock in the urban area, within certain areas, like there is the historical right to farm in the city. I have not encountered planning issues at the farm. We built it in a warehouse, I mean it was available for other businesses to hire but nobody was renting it and it had been damaged in a fire. It was similar to a car park, you know, a kind of unwanted. And we have not asked for permission. We just do it. But also we know it is so new, we are going to encountered things for the first time, so if we are asking questions to planning departments or environmental health, this is the first time they would have ever been asked about this kind of issues. In environmental health, they have just started to work on that kind of things and it is quite interesting which new policy they bring together connected to food and hygiene and that kind of things. I guess the one zoning issue we have had is that we are not in an agriculture zone. We are in an urban zone and our water prices are based on being urban, not rural. So we cannot get agriculture discount for our water supply because we are not considered the rural user and once they are will be zoned as rural, and it will not be, it is an industrial area, the water price will not be changed.

Interviewer: So water is more expensive for urban farmers than rural farmers?

Interviewee 3: Yes, they may have a point in our case. You pay for the supply and the removal so sewage. In rural farming, context water does not go back to the wastewater; it just goes on the land typically. So they are not using the sewage system. So why should they pay for it? And in the city, they would say: you are using the sewage like we are using the sewage. I think there is some logic. But other urban farms are also subject to this problem and it would be nice to see a policy change that allows previously industrial spaces to be considered as rural in the area of a city. I do not know how it would happen. But a lot of planning laws that you may encounter I heard from others have been when you want to develop a big new facility and you start to ask the local community what they think. And it is more about how you interact with the concerns and how you answer your conversation that is about what you are doing. They are often worried about air pollution or noise pollution. If you are in an industrial estate like our farm, we can make smells all day long.

Interviewer: Is it an issue for CEA?

Interviewee 3: No at the moment that you would hear outside the building. But if we would smoking fish, it would smell fish all the time. But when you are in an industrial estate, you are in that zone where you can do that kind of things. But when you start talking about multi-storey car parks, you might be in the centre of the city. There might be apartments next door. You have to start thinking about the impact on the residential space.

Interviewer: I am analysing the Prince Street Car Park which is strictly connected to the hotel. Do you think that pollution can be an issue?

Interviewee 3: I think that there is not very much pollution from this type of farming. I think it is more about the community understanding what are you doing and does not worry that there will be pollution. Light pollution is a real challenge, so you need to be careful about that. Sometimes it is cool, but you do not want to live in an apartment next to the building that is dayglow 24 hours a day.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 3: Well, that kind of opportunities which benefit local communities. I mean when the Council want to build new apartments or hospital, they need to pay back to the local community. And I think there was a couple of occasions when they looked at urban farming. With Bristol Fish Project, we work with an architecture practice in London called Funigan & Lawrence to develop an aquaponic system that can be fixed on the side of big commercial sheds. So we are not talking about urban but maybe per-urban areas. We are trying to create a modular system that they can add to their plans to help them get the planning permission. It is not our motivation to get through planning, but we saw it as an opportunity.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 3: There should be a social initiative so you may be able to do it with less initial investment than if it is a for-profit initiative. I am really pro using multiple revenue approaches. And I like the idea that you can get more than just lettuce out of the farm. You can give people skills and you can help revive the community that is maybe depressed. We have always worked with low-income areas with our projects. So when I said you could do it purely commercially, it is more based on my observation, it is not what I was trying to do. I have always been interested in creating a kid of ecosystem rather than businesses. And that is not something I have achieved as much as I would like either. I think my dreams for the farm was to have a restaurant, have a school, to have different small agricultural businesses which are working together. Maybe to do some local food distribution. We have never had the revenue and stuff to make that happened. But it has been a good opportunity to start. We are just getting a space, working on aquaponics is exciting, but we would need a lot more money to do all these things. But I do think it makes your business more robust if you have a lot of different incomes. So for a big car park in a city having a café would help with the funding of the business.

Also when you look at the value chain of a product when you are looking at food production, it is like the worst margin product that you could ever choose to sell. And each layer of the value chain is where the more money gets made. So the farmer makes the least amount per salad, the guy that moves salad from one place to another makes a bit of marginal top of that and then you have got the retailers, cafes, supermarkets where they ever got a bigger margin.

When the food is getting processed, then there will be a company that makes a margin. So like 60 percent of the money that you can make from a salad you cannot make on a farm. So if you could bring some of those businesses into your farm, e.g., if you can say we process it, or we sell it here at the farm gate, you are going to make more money than if you just sold wholesale out of your farm. So there is an economic logic to not only farming.

Interviewer: That would probably reduce food miles.

Interviewee 3: Yeah, and when you talk about hydroponics and aquaponics and their products, they benefit from being grown close to the consumer. Because then they are less likely to be wasted. They are like the most waisted thing I think. They are summer crops and they are throne everywhere along the value chain.

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 3: There is a weight question. So the engineering of the car park needs to adequate for aquaponics. Aquaponics is very heavy. Hydroponics is not heavier than a car, so they do not have to worry about the weight. But you should probably keep your fish production in a basement level on the solid ground. And then there is this question of advanced technologies. So in most of this car park, you would need to use augmented lighting to make the light adequate to grow intensively. And at the moment I think 5 acres of solar power is needed to generate one ack of LED power. So it is not efficient when you think of it that way. Maybe this is a part of this new system that you are not geographically connected so you can make your food there and produce the energy over there as a new freedom. The technology is changing all the time. So when I hear this as a challenge, I am saying that there is a constant improvement in energy generation so it will not always be inefficient.

Interviewer: Do you use natural lighting for your farm?

Interviewee 3: We don`t but we have in our pilot project and in our architectural concept designed the is natural and supplemental lighting. I think we have come to believe that mixing natural and supplemental lighting is currently better. But it depends on your circumstances. We have a warehouse. It is not like we would have a field. People are asking these questions: you have these privileges and money why you just do not build a bespoke farm in the middle of the city and that is not what we are talking about here. We are trying to use derelict land, or we are trying to use recycled materials. So we have to start with what we have. I do not know if there are many pollutants to still worry about in a car park but then probably you are not going to use the ground to build your farm, you will grow in containers whether you are doing hydroponics or not so then you do not have to worry about the pollution if you would put soil there then you should probably worry about it. So it gives you a sort of freedom not using soil.

I guess another limitation is that it is expensive. So you need to know why are you doing it and have a business model that is suiting what are you doing. It is expensive but it creates a lot of jobs and it disadvantages community that is suffering from self-confidence. It does not matter that it is quite expensive because you are getting more benefits. You are getting food, but you are getting all these social benefits as well.

Interviewer: Do you think there any other architectural limitations for this adaptive reuse process?

Interviewee 3: Disadvantages may become advantages. One thing I have learned from our intensive farm is that you can`t really on people going to your structures, you need to take it to a professional company. But it depends if you want to be a labour intensive or do you want to be efficient. A lot of farms use now conveyor belt systems so in some way these ramps and things may be cool for creating a conveyor that really can go around the farm because it is designed for cars. So ramps may be an advantage. People should move inside in a different way. So there is like a people access and cars access. So you could have a movement of plants and a movement of people. It thinks that for security as well it is quite nice to be able to isolate things for example, by having layers. SO having a layer with a farm in one of the floors of the car park is maybe better than having a one open structure with the same volume. It can help to reduce the spread of diseases on your farm as well as insects. Elevators will be very useful. You would have to invest in the cladding to have a controlled environment. There are lots of good technical materials out there. They are just expensive that is it. We are already indoors but I used spray isolation in a celling, we have about 5 cm of insolation. That was to stop humidity. It may be the same for car parks. We have an asbestos ceiling. So it was impossible that the water would gather on the ceiling and drip back to the system. We had to minimise that risk. And we found an aquaculture foam that is supposed to stop the condensation. So we had this. But then it cost like 10000 £ and it is not a big warehouse. So in every layer of your car park, you are going to spend a lot on insulation if you need it. If it is just to stop condensation, it does not need to be 5 cm it can probably be thinner. I do not think the carparks are designed to be well insulated.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 3: We should use resource-saving technologies. We only use recirculating water harvesting systems. In these terms, our systems are more efficient than a normal fish farm. We do not have water harvesting because we have asbestos in a roof so do not collect water from that. That is a problem with older buildings. So we avoid the asbestos as much as we can. There have been investments that we have been able to afford. So, for example, we would have used LED lighting. But our funder said it was too much money. But for us it is for research. We proof our concept but we would much prefer to use sustainable technologies.

Interviewer: Which technologies?

Interviewee 3: Using LED would be good. We would love to have PV on a roof. It would be great to have greywater because we use a lot of water, we use 10000 tonnes of water in six months. Maybe you could do a piece of a car park rather than a whole car park to show the concept, make mistakes, mess around and then you would have a basis to extend the project.

Interviewer: Would you consider the adaptive reuse of the inner-city multi-storey car-parking structure as a value in terms of environmental sustainability?

Interviewee 3: Yeah, I think there are clear aspects of environmental sustainability, like shortening the delivery chain, waste reduction. But there are also challenges like lighting, being as efficient as possible in the future. Social sustainability could be very interesting. The inner-city multi-storey car park is probably worth 6 million pounds in real estate terms just for the land even though it is a car park. So you need to prove that what you are doing is worth more to the community than another apartment block. And we are talking about the city which has serious accommodation problems. So this is a challenge for us to talk about food when there are more important topics for the council. It is a hard one. It is tough to compete with that other pressures for that land. I do think that the city needs to experiment with the future to be prepared. So there is always this idea that cities that care and are forward-thinking are investing in that kind of stuff for their futures.

Interview 4

Interviewer: What are the key planning limitations for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 4: You need a planning application if you are going to have a change of use in building or any site. So in our situation, it was quite easy for us to get planning permission for a change of use of the site to build aquaponic farms. We have actually done that. It can be done. I think depending on the size of it and the place of it you would have questions from the planning department about what are doing so I think the limitations I guess would be it is built as a car park. I do not know how difficult or not difficult it would be to convert it but there are, I think there are precedents for people doing this kind of thing. We have done it on this site. So from a planning point of view, this will not be impossible.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 4: I think there are many and I think it comes as part of planning permission you have to point to where you are going to benefit the city and if you link to any plans or programs or ambitions of the city to do that sort of things. So planning permission can point to where you might meet some of the needs of a city as a laid up by the local authority and in Bristol, there are lots of them, for instance, these around food policy and sustainability and so on.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 4: Yeah, well again we have already discussed, I guess you would have to decide what is that hydroponic farm for. Is it a commercial enterprise, is it a business making a commercial enterprise, commercial farm or is it a community project? Is it a combination of those? Does it provide jobs? Does it provide education opportunities? So, I think if I was doing it, I would make it quite dynamic space and it would not just be hydroponic vegetable production. If I was to do it, it would be a kind of food innovation centre for lots of different types of food production that would be complimentary and could contribute to the circular economy. And then it opens up opportunities for events and public space and retail and all sorts of things

Interviewee: What kind of additional facilities should be developed there?

Interviewee 4: Well, I think there are a few examples of the sort of, for example, you have got some container villages where they have a lot of different organisations. So, I would say the kind of innovation centre where you would either in shipping containers or, depending on what part of the car park, if you are on a rooftop, you could have different structures adapted into that space that would house lots of different businesses, like an incubator you might call it. Or a home for lots of different start-up organisations. I think that is what is needed. There are lots of these things around. There are not many that are using food in innovative ways. And you know you and your hydroponic lab, your hydroponic unit could be the centrepiece as we have already established, for example, if this is like ours it scale up into that and we already know about the initial stages. Because start-ups actually have a proof of concept already.

Interviewer: Would you think of this as a permanent or temporary use?

Interviewee 4: Yes, I think what we have learned here is that I guess nothing is permanent, so it depends what you mean by permanent temporary. But what I would say is how you would want to manage what you put there. So, if it was a business that was starting up large, like ours, you would want at least five years. For our pilot project here we expected we would only need two years being here but we are already here for three years. So, you need to adapt the tenure to the project. A shorter time the less you can do and achieve. I think some people would want five years or ten maybe for their project before they want to move somewhere else.

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 4: Yes, I think we are an example of farmers who are still trying to find a profitable business model. So, nobody has really proved a sustainable and profitable urban farming model. And lots of people trying in America, Europe and Britain. So, everybody knows about it a lot of people trying it. It is also a problem in terms of Bristol and lots of cities, the case for urban agriculture being benefit the city is already established. Bristol has a food policy. And then they produce a good food for Bristol. You can see that increasing urban food production is one of the main aims. So, the familiarity and acceptability of the concept are already established. It is just about making it sustainable.

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 4: I would say more about the key opportunities rather the limitations. I do not know if you are planning to put the hydroponics on the top of it and if whether there is an open structure. I looked on google maps and I do not think the car park is open and it seems to have a roof on it. So, I think in terms of using what we call controlled environment agriculture or indoor farming that is a lot of opportunities, for example, you could build structures into the spaces of the car park. To grow the food you need a sort of a controlled hygienic environment if you want to do in a commercial way. You could quite easily create those structures in car parks and in car parks the first opportunity is access. I have always thought about how car parks are built. The vehicles have access to every floor with ramps. You could actually get the equipment there, to make the build there- it is accessible. And then the limitations would then be paths that you would need access to electricity. So that might be a limitation. You would also need access to some ventilation systems which you could build into your system. If you had a less controlled environment and perhaps more community project rather than a commercial project, you could utilise less technical structures or indoor structures. That depends if you had access to natural light. So, I think it could be quite a good space to build a hydroponic system. I guess there would be a height limit.

Interviewer: Is it important for hydroponics?

Interviewee 4: Well, it is not. For vertical farming, you use the vertical space and many people think that the way forward is to have as high a possible space to go sort of 50 metres high hydroponic systems. We do not think so. So, in that sense, it is probably not a limitation. For us, it should be a kind of human scale, a system which would fit into the car park. But you need water- access to water. I mean you could harvest water from the structure which would be quite interesting. You would just build more structures for whatever you need. You would need to build units into it so you could do things you wanted to do. I do not know if this would be heavy. I think no more than a floor full of cars. The weight of all of those cars would be a lot more than you would need to build in. Although well obviously you have to check the weight of the system. Given that it is built to hold lots and lots of vehicles, the weight will not be an issue. If you think you might have a problem getting a shipping container to the upper floor maybe smaller ones. But I think these car parks are not probably built for trucks. I think that is kind of irrelevant because all the shipping containers are for walls and roof and you can just create those. So, the reason that you might use a shipping container is that if during the weekend or any night if someone wants to come and break into damage our system- it is quite difficult to do that. I think one good thing about a car park would be a security. Because you have pedestrian access and vehicle access. I think they could be controlled very well.

Interviewer: Which architectural modifications should be applied during the design process of the adaptive reuse of inner-city car-parking structures for CEA in order to address the opportunities and limitations of such an up-cycling?

Interviewee 4: Yes, such as electricity and water and ventilation, would be key. I guess they have the electrical connection and access to the electrical system. Water can be brought in. It does not use a lot relatively but access to water systems would be good, for example, like I said harvested from the structure. Energy. What if you could put solar panels covered on the top to harvest energy to run the system.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 4: The controlled environment hydroponics, that you would perhaps fit into the multi-storey car park would need energy supplies. People sometimes think it is just about heating but it is often about cooling as well depending on the ambient temperature. So, access to renewable energy. The roof of the top of the car park would create a space to put in potential renewable systems. So, that could be a solar or wind-powered system as well as harvesting rainwater. Those two things I think would be key to this controlled environment and urban sustainability.

I think you would need to adopt the kind of sustainable passive system for ventilation. So, I think you could get some clever things to adopt a more sustainable system to control heating cooling and ventilation in an efficient way.

If it was on the top storey that you would have you could utilise more natural light systems, you could have greenhouses up there and you could be using more natural light and grow seasonal things. That could become the first vertical farm in Bristol. One of the ideas of vertical form is that in one space you stack up hydroponics. But the other is to use different things on different floors and they could be all connected so you could have aquaponics farming, on the roof you could have chickens and bees and all of this stuff and greenhouses. On lower levels, you could have things that do not need natural light like the aquaponics. Then you have insect farms and mushroom farm.

Interviewer: Do you think that all of that is allowed in the city centre?

Interviewee 4: You have to check the restrictions. It would be a brilliant space to do that. You have got the accessibility for the building and then a few commercial facilities around which you could be buying your products. You will be creating jobs, so, contributing. One of the ambitions of Bristol is carbon-neutral zero waste by 2020. So if you are a circular economy system, you are integrating into: reducing waste, renewable energies, jobs, commercial, education, retail, everything would be in that. People are starting to do that but we need more of it. But you need funding and planning and political acceptance. Who owns the car park?

Interviewer: The city council owns it. This could be a planning limitation because these car parks are considered as a significant source of income for the city. The city council does not want to develop new car parks but to use these which already exists. And probably that may be one of the limitations for the adaptive reuse process. But the plans aim to limit the access of private cars to the inner city.

Interviewee 4: So, they will be free but if not, you could use half for the cars and half for the farm.

Interview 5

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA?

Interviewee 5: The financial viability for using the car park for farming is a challenge because you need to get enough value out of the sale of the products that you grow there to fight off the developers. That is quite difficult to do unless you make it mobile. And what is very interesting about car parks is that every parking bay is 2.4 x 4.8 meters. So, you need to develop a module that you could work with that would allow you to have a sort of mobile activity, a mobile farm. Because if everything was made to this module, it would fit almost any car park. So, the viability of it would be a lot better because you could get a meanwhile use.

Interviewer: Would you think of this as a permanent or temporary use?

So, a lot of these car parks are empty, but people do not want to commit long term to the use for agriculture potentially because they see there is a development opportunity. And if you want to get to a position where people move from that perception to the position where people see the car park as a potential agriculture structure you need to overcome that otherwise the idea never happens. So, if you make everything in the way that you could migrate from one car park to another it would be much easier. You have got a fantastic advantage in the car park for agriculture.

Interviewer: What are the key architectural opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 5: Good load-bearing floors, the floor-to-ceiling height is not good enough for anything else. But quite expensive energy costs. Another thing about car parks is that they are generally in the shape of rectangles. So, you can drape any ETFE skin over the building very easy to change its energy performance. And you do not have to worry about any building regulations because it is not heavy at all. And that would be a very cheap thing to do. You probably need sponsorship for your project. So, one people you can approach is VectorFoiltech. So, Vector Foiltech have invented ETFE technology. They are based in London; they are quite innovative. When they started, it was about creating an artificial climate. So, their idea was originally to have a floating cloud. So, it has started with an ecological band. Other people who own car parks is the National Car Parking. They probably have more control than the local authority. But you will be looking for a change of use, so what you want are the sponsorship and the political support. So, they may sponsor you to get one of those three done.

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 5: Yes, it is because the owners of car parks are looking now for alternative uses. A lot of these structures are empty and they do not know what to do with them. A lot of these properties are also in shopping centres. Retail development has had rock bottom at the moment. So, there is a number of empty properties where first of all there is car restraint policies, people are not encouraged to drive in any longer and then they cannot sell it for development. So, they are looking for a use for them. Do you know Carl Turner?

Interviewer: No I do not.

Interviewee 5: He is a person converting a car park in Peckham at the moment. Carl is converting the Peckham car park for a series of workshops. He knows garages quite well because he has also developed Pop Brixton and that is on a site of a former garage, where they actually knocked down the garage and then put a series of containers. I think it is silly that they knocked down the garage.

The Peckham car park has been a growing concern from 5 to 10 years since people started to develop the rooftop. So they have got the rooftop there and Carl dealt with the access to the rest of it. So, there is a bar there and a dance club during the night. They also have sculptures there. It is extremally popular. You have got a beautiful view of the rest of London. They started in 2010, so I think it is still there. But now they are doing the whole beneath. So, they have started on the roof and it used to be a great experience. So, what you would do is you go to Peckham, you would have to walk through these horrible streets, you get to this car park and you get in this lift that does not look like it is going to work, you go up and you think what I am doing and you get to this bloody rooftop. So, it used to be quite thrilling. They have there also exhibitions in the summer.

It was a very unsuccessful car park at the time it was built. Is was one of the last which what was called the Greater London Council did. A lot of money went into it. So, in your car parks, if you have a mobile system, you could progressively close all the floor and implement agriculture without removing the function immediately.

Interviewer: So, then it could be again an interim solution?

Interviewee 5: Yes, because, half of the difficulty is to get the idea to start. And one of the best ideas to get the thing to start is to collapse the old regime progressively. So, you progressively shut the car park. In the beginning, you could use 80 percent for experiments. There should be a revolution in the inner-city areas now because cars are taking the area. But you will need water. So, if you have got track and vans that could move around easily and something for growing food on a module of 2.4 x 4.8 m compatible you would have a very easily scalable solution which you could deploy in many places.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 5: All of these technologies can be done in a module. If you want to harvest greywater from the roof, it can be easily done in these car parks which have drainage. So, all you do is you take the roof drainage pipe where the water is going and you just tap off that. You just take the water from that. So, you have got it already, you are not going to do better than that. It is going to be very cheap.

If you wanted to get solar energy, you just put 2.4 x 4.8 modular designed solar panels on the roof in a right orientation and you would run the cabling from there to your unit converters. If everything were modular, you would be able to put it to another car park. If you wanted to save the energy in hydroponics, what you do is cover the house skin just with the curtain of the ETFE. It is a very lightweight foil, an entirely transparent material that is used for lightweight roofs but it looks like plastic. So, in car parks you have got quite thick concrete mass, so that stabilises temperature, you have got a difficulty because you need to stabilise light into the in-depth plan and then you have got heat. You have to take the balusters off and you can just drop the curtain down. You tension that curtain on the bottom and clip it and as long as this material was very cheap and economical and you can reuse it. You know that the dimensions are almost the same across all car parks so the fixing points will be the same. And that would save a massive amount of energy.

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 5: Well, the floor-to-floor height is generally low in car parks. Look for that in Neufert. Usually, these car parks are very much lower than other structures and the door is only 2 meters. If you have some additional space, you could use it for cheap storage. Storage space is really valuable. You must also put insulation to the top because you do not want things to frost over.

Interviewer: What about the loads?

Interviewee 5: I do not think you should have any difficulties because they are prepared for high capacity. But you should check the engineering structure. If you do modules, you could distribute your modules accordingly.

Interview 6

Interviewer: Oglądałam na stronie Fundacji Transformacja wasze projekty, jest ich całkiem sporo. Czy przed ich realizacją potrzebujecie pozwoleń ze strony urzędu miasta?

Interviewee 6: Absolutnie żadnych pozwoleń z tego względu, że właścicielem budynku w którym robiliśmy ostatni projekt jest osoba prywatna więc korzystaliśmy po prostu z takiej opcji. Użeranie się z biurokracją zwłaszcza w momencie kiedy mówimy o systemach, których nikt nie zna, które są pilotarzowe, eksperymentalne, na samo hasło aquaponica urzędnicy robili wielkie oczy, to nie ma sensu. Mieliśmy taką próbę, próbowaliśmy od miasta dzierżawić lokal, ale skończyło się to fatalnie i absolutnie nie chcę do tego wracać.

Interviewer: Czy technologicznie zaawansowane formy produkcji żywności w miastach nie są zbyt popularne?

Interviewee 6: To dopiero gdzieś tam zaczyna wchodzić do świadomości ale na pewno nie urzędników.

Interviewer: Jakie są największe bariery które spotykasz jeśli chodzi o planowanie, zdobywanie pozwoleń na tworzenie farm w miastach?

Interviewee 6: To zależy jak na to patrzeć. Jeżeli zamierzasz prowadzić projekt komercyjny to niestety musisz uwzględnić wszystkie wymagane pozwolenia, zwłaszcza ze strony sanepidu jeśli chciałabyś taką żywność sprzedawać. Natomiast my zajmujemy się tworzeniem rozwiązań, które będą miały zastosowanie w szerokiej skali mam nadzieję w niedalekiej przyszłości. Natomiast na pewno nie w obecnie istniejącym systemie biurokratycznym. Jeżeli chcemy się dostosować do tego systemu biurokratycznego to jesteśmy skazani na całkowitą klęskę cywilizacyjną z tego względu, że istniejące przepisy prawa absolutnie nie uwzględniają takich zjawisk jak efekt cieplarniany, degradacja środowiska. Jeśli przepisy nie uwzględniają poszanowanie matki ziemi, planety na której przyszło nam się rozwijać cywilizacyjnie, to znaczy, że one są podstawą degradacji tej planety a to oznacza, że takie przepisy znajdują się znacznie niżej w hierarchii praw natury to ja je zwykle ignoruję. I wtedy wchodzisz w taką przestrzeń,która jest nacechowana dosyć dużą wolnością twórczą i możesz wprowadzać rozwiązania, które mają sens, są logiczne, są zgodne z prawami przyrody i przede wszystkim służą wyższym celom, czyli uratowaniu naszej cywilizacji od globalnej katastrofy.

Interviewer: A jakie są możliwości jeśli chodzi o planowanie? Czy są jakieś wspólne priorytety?

Interviewee 6: Po pierwsze urzędnikom trudno jest zrozumieć to co my robimy, a po drugie żeby wydać określone decyzje, które miałyby umożliwić wprowadzenie takich rozwiązań. Najczęściej po prostu takie rozwiązania nie zostają wprowadzone bo nie spełniają jakiś tam przepisów prawnych. Natomiast jeśli postawimy się w pozycji takiego urzędnika, który też jest konsumentem, też potrzebuje zdrowej żywności, też chciałby się dobrze i zdrowo odżywiać i przede wszystkim tanio to ci ludzie z takiej perspektywy widzą olbrzymie korzyści. Ale mają często związane ręce skostniałym aparatem prawnym. Po prostu nie ma odpowiednich ścieżek legislacyjnych, które umożliwiałyby zrealizowania takich bardziej ambitnych projektów w instniejącym systemie społeczno-prawnym. Przykłądem może być restauracja, która została szumnie otworzona w Łodzi po czym z równie wielkim hukiem została zamknięta z tego względu, ze restauratorzy, którzy wymyślili sobie bardzo ciekawą konwencję przygotowywania potraw w oparciu o insekty absolutnie nie byli w stanie przebić się przez wymogi sanepidu. W pzrepisach prawnych dotyczących żywności, białko z insektów nie jest wogóle dopuszczone do konsumpcji przez człowieka. Więc mimo tego, że jest to najczystszy rodzaj białka jaki można w tym momencie pozyskać ześrodowiska, nie możesz oficjalnie go sporzywać, ponieważ zabraniają tego przepisy prawa. MY robiliśmy taki projekt oparty na takim insekcie, który nazywa się hermetia. To jest taki owad, który bardzo szybko nabiera na wadze, stanowi doskonałe źródło białka nie tylko dla zwierząt, ale też dla ludzi i w Azji są zjadane, więc dlaczego nie w Polsce- odpowiedź znajduje się w skostniałych przepisach. Ale to się zmiania, UE też dostrzega konieczność poświęcenia większej uwagi owadom i udostępniania tego typu rozwiązań. Raporty ONZ też wskazują że za 50 do 100 lat większość białka zwierzęcego będzie pochodziła z farm owadów. Ale tempo tych zmian jest nie współmierne z potrzebą ich wprowadzania.

Interviewer: Teraz zadam pytania bardziej dotyczące mojego doktoratu. Jeśli chodzi o wrdażanie hydroponiki czy aquaponikiw istniejących budynkach- jakie są możliwości architektoniczne a jakie są największe bariery jeśli chodzi o wdrażanie takich instalacji?

Interviewee 6: Jeśli chodzi o już istniejącą zabudowę, to główną barierą jest sama nośność konstrukcji tego budynku. Parkingi są z reguły projektowane na duże obciążenia, więc tu bym się raczej nie przejmował, ale trzebaby sie skonsultować z konstruktorem, który powinien sprawdzić nośność. I tutaj na podstawie takich wyliczeń można obliczć jaką ma nośność poszczególne piętro i na tej podstawie należałoby zaprojektowac cały system aquaponiczny czy hydroponiczny koniecznie z zamkniętym obiegiem wody zasilanym z wody deszczowej i to jest potężna korzyść ponieważ każdy budynek jest powierzchnią uszczelnioną, która doskonale gromadzi wodę z otoczenia i najczęściej problemem jest odprowadzeniem nadmiaru tej wody do sieci kanalizacyjnej natomiast w przypadku zainstalowania systemów aquaponicznych czy hydroponicznych można tą wodę wykorzystywać w nieskończoność właśnie w obiegu zamkniętym. Kolejna bariera to przepisy dotyczące sprzedaży produkowanej żywności. Ale też jest to do przeskoczenia. Z barier bardziej znaczących jest też kwestia zanieczyszczenia powietrza w mieście. To jest czynnik, który rzutuje na jakość produktu, ale też można się przed tym trochę obronić i na tyle uszczelnić cały budynek, żeby kontrolować dopływ tego powietrza i filtrować to powietrze. To wiąże się z dużym nakładem energii na zaopatrzenie takiej farmy w energię elektryczną do obsługi takich nstalacji. Hydroponika opiera się na ciągłym krążeniu wody, więc tutaj dużo energii zużywają pompy, które napędzają cyrkulację takiego zamkniętego obiegu wody. Ale to też można rozwiązać przez zamienienie dachu w farmę fotowoltaiczną i cały system upraw napędzać energią słoneczną. Jeżeli posłużymy się energią konwencjonalną i będziemy próbować zasilać takie duże miejskie farmy z energii elektrycznej w oparciu o spalanie węgla to możemy zapomnieć o jakimkolwiek efekcie ekologicznym takiego rozwiązania, więc tylko i wyłącznie odnawialne źródła energii mogą stanowić źródło zasilania takiej farmy jeżeli uwzględniamy cały cykl życiowy takiego obiektu.

Interviewer: Jakie jeszcze instalacje wspierające zrównoważony rozwój mogłyby być tutaj używane?

Interviewee 6: W naszym projekcie BioSchronienie wykorzystywaliśmy biomasę odpadową pozyskiwaną z najbliższego otoczenia, czyli takiego fragmentu parku, który znajdował się w obrębie kompleksu fabrycznego. W parku były posadzone drzewa liściaste głównie lipy, jesiony, klony, które co rocznie na jesień zrzucały olbrzymie ilości liści, które się grabiło i wywoziło do kompostowni. Natomiast w pewnymmomencie my zaczęliśmy przejmować tą biomasę i na bazie tej biomasy stworzyliśmy rozwiązanie, które nazywa się grzewczą pryzmą kompostową. Czyli wytwarzaliśmy kompost w procesie gorącego kompostowania i przy użyciu tego kompostu realizowaliśmy projekty związane z odbudową gleby i wytwarzaniem tej gleby. Na glebie w ten sposób wytwarzanej i pozyskanej na miejscu hodowaliśmy część warzyw. Natomiast energia, którą generuje taka pryzma kompostowa wykorzystywaliśmy do ogrzewania wnętrza tej naszej przestrzeni. To było 175 m2 powierzchni i 5m2 wysokości. Byliśmy całkowicie odłączeni od centralnego ogrzewania z sieci. Wykorzystywaliśmy tylko alternatywne źródła energii, żeby wykorzystać energię elektryczną i cieplną.

Interviewer: Jakie dodatkowe funkcje powinny zostać wprowadzone do takiego budynku razem z farmą miejską, żeby można było produkować żywność i przetwarzać a następnie sprzedawać mieszkańcom miasta bez konieczności transportu na długie dystanse?

Interviewee 6: My realizując projekt Bioschronienie celowo wybraliśmy lokalizację tego Bioschronienia na drugim piętrze budynku z tego względu, że bezpośrednio nad naszym pomieszczeniem znajdowała się olbrzymia połać dachowa, do której mogliśmy mieć dostęp z wnętrza naszego bioschronienia. Niestety nie doszło do tego z tego względu, że po trzech latach realizacji tego projektu, jak już doposażyliśmy budynek w wewnętrzną klatkę schodową i windę , którymi można było wychodzić na dach, zmienił się właściciel budynku. Nowy właściciel bardzie j skupił się na wynajmie pod użytkowników komercyjnych i czynsz tak bardzo wzrósł, że nie było nas stać na dalszy wynajem. To też widzę jako barierę, jeśli decydujemy się na wynajęcie przestrzeni od miasta, to musimy mieć gwarancję, że będziemy mogli ją użytkować do końca realizacji naszego projektu albo co najmniej na okres 25 lat. Żeby mieć pewność, że nie spotkają cię zawirowania, które przewrócą projekt do góry nogami i nie pozwolą go doprowadzić do końca. Planowaliśmy rozwinięcie farmy na dachu budynku. Całe plony planowaliśmy przeznaczyć na zaopatrzenie restauracji, która znajdowała się w kolejnej części tego kompleksu fabrycznego. Tutaj już mielibyśmy skrucony dystans pomiędzy produkcją a klientem.Druga opcja to przekazywanie wyprodukowanej żywności w bioschronieniu do kooperatywy spożywczej, czyli do oddolnie zbudowanej sieci dystrybucji organicznie produkowanej żywności ekologicznej. Takie kooperatywy spożywcze są już sprawdzone na świecie, ten mechanizm bardzo dobrze funkcjonuje jeśli chodzi o taki układ, który możemy nazwać miejską farmą. Kolejna rzecz to system dystrybucji typu paczka dostarczana przez kurierów rowerowych.

Interviewer: Czy Ty uważasz, że taka frma miejska oparta na zasadach zrównoważonego rozwoju może zastać wprowadona jako rozwiązanie stałe, czy raczej jest to coś czasowego?

Interviewee 6: Może to być oczywiście długoterminowy biznes. Natomiast, na pewno nie tylko i wyłącznie w oparciu o hydroponikę. Z tego względu, że tutaj widzę kilka barier związanych z ceną takiej żywności i jednocześnie eliminacją pewnych grup społecznych, których nie będzie stać na taką żywność. Zamożniesze grupy społeczne bardzo łatwo ulegają pewnym modom. Teraz mamy modę na żywność eko i organiczną.Więc jeśli ludzie chcą płacić dużo za żywność z farm aquaponicznych to jest super, ale po pewnym czasie ta moda się skończy i ludzie zaczynają powracać do swoich utartych schematów żywieniowych i wtedy załamuje się popyt na tego typu towary. Więc jeśli nie ma dywersygfikacja takiego systemu wytwarzania żywności to bardzo często niestety dochodzimy do ściany, kończą nam się odbiorcy i taki biznes przestaje być rentowny. Natomiast instalacje hydroponiczne generują dosyć wysoki koszt utrzymania. Jeżeli są prowadzone na skalę komercyjną i są prowadzone metodą organiczną to pytanie co generuje taki wysoki koszt. Często jest tak , że jadąc na tych hasłach organiczny, ekologiczny ta cena jest sztucznie zawyżana, zeby generować jak najwyższy zysk. Więc pytanie jaki jest nadrzędny cel takiej farmy. Czy jest to jak największy zysk czy jest to wytwarzanie żywności dla lokalnej społeczności. Ja jestem zwolennikiem systemów non profit, które tak na prawdę nie dokońca są non profit. Tutaj nie eliminujemy roli pieniądza, natomiast 100% dochodu wygenerowanego przez taką farmę są przywracane do całego ekosystemu usług związanych z prowadzeniem farmy. Czyli środki są reinwestowane w rozbudowę infrastruktury związanej z produkowaniem i przetwarzaniem żywności na farmie, latwiejszą i bardziej zrównoważoną dystrybucję wytworzonych produktów. To powoduje zbudowanie lokalnej społeczności, która zaczyna tworzyć autonomiczną jednostkę gospodarczą, ten pieniądz zostaje w lokalnej społeczności. Kolejne korzyści to finansowanie szkoleń, szkół, przedszkoli, całej infrastruktury takiej hardwarowej, twardej, która tą lokalną społeczność umacnia. Więc tutaj bardzo wykraczamy poza całą ideę produkcji żywności. W kontrze do takiego systemu stoi komercyjna farma, która po prostu ma generować zyski.I w momencie kiedy te zyski zostają wygenerowane i trafią do udziałowców to my jako społeczność , która przyczynia się do wygenerowania tych zysków, tracimy nad nimi kontrolę bo do końca nie wiadomo na co te pieniądze zostaną później przeznaczone.

Interviewer: Czyli może to być coś stałego, ale powinno wspierać lokalne spoleczności?

Interviewee 6: Absolutnie tak. Przykładem jest Detroit albo Kuba, Havana.

Interviewer: Jakie dodatkowe funkcje można rozwijać przy farmach miejskich w celu wskierania lokalnych inicjatyw i społeczności?

Interviewee 6: Kolejny projekt, który też jest opisany na stronie, to jest miejska farma. To był projekt realizowany w strefie podmiejskiej, na obrzeżach Łodzi, ale można tam było dojechać ścieżką rowerową, na terenie szkoły rolniczej. Szkoła dysponowała olbrzymim obszarem uprawnym, który był praktycznie nie wykorzystany. Z urzytkowanego terenu powstało mnustwo odpadów organicznych, składanych na wielką hałdę, która zaczęła sprawiać problem bo zaczęła generować nieprzyjemny zapach, zanieczyszczać lokalne wody czy przyciągać owady. Obok były nieużywane szklarnie. Zbudowaliśmy partnerstwo z tą szkołą, zajęliśmy się głównie przetwarzaniem odpadów organicznych iwytwarzaniem na bazie tych odpadów kompostu, na którym moglibyśmy wytwarzać organiczną żywność. Projekt bardzo szybko zacżął przynosić dochody, plony były duże. Generowaliśmy energię cieplną do ogrzewania szklarni, produkowaliśmy bardzo dużo dżżownic , które przetwarzały resztki organiczne. Mieliśmy wtedy świetne narzędzie w rękach, żeby stworzyć tą lokalną ekonomię i oprzeć się na tych odpadach. Każdy projekt, który jest związany z wytwarzaniem żywności powinien być związany z rozwiązaniem, które będzie odbierało od konsumentów, którzy kupują od nas żywność wszystkie resztki organiczne , które powstają w kuchniach. To powinna być kolejna linia takiego obiegu zamkniętego, która recyrkulowałaby bardzo cenne substancje pokarmowe w takim systemie. Więc to już jest bardzo ciekawy mechnizm, żeby rozpocząć edukacje, np. Na temat tworzenia gospodarki systemu, obiegu zamkniętego. Takie systemy generują też bardzo duże przychody, z których można zfinansować całe systemy edukacyjne przygotowujące następne pokolenia do wdrażania i tworzenia takich rozwiązań. W ramach tego projektu planowaliśmy uruchomić kierunek związany z budownictwem wykorzystującym materiały naturalne. Słoma jest idealnym, ekologicznym materiałem budowlanym. Zrealizowaliśmy projekt pilotarzowy ale zablokowano nam możliwość działania.

Interview 7

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 7: It is not familiar with urban farming. There are some excellent examples of it. The word `adaptive` is a new concept, a new concept. The `reuse` of existing buildings was always in use. I think that theoretically, adaptive reuse has a particular focus on it. I think that the reuse of existing buildings is whether they are redundant and whether the new use is welcomed. I do not think we see it hugely. But that shows the local authority engagement with the reuse of local buildings. But I do think this is an accepted concept and approach in the building industry. Therefore, I think it is a viable approach. It just depends on whether or not the building has value and significance. If it is either historical heritage building or has any kind of listing or has a community value, that is where that kind of perception is that the building is an element of an identity of a place and that is what you need to involve in your project and show to the planner that you plan to give something back by the reuse. They may say they want to knock the building down and build something new rather than reuse it.

Interviewer: Would you think of CEA as a permanent or temporary use?

Interviewee 7: Car parks are interesting developments build because of the land shortage for parking cars, it is not a building although there are buildings build on it. Car parks were always seen as something temporary and one day someone may want to develop that land so the farm would have to move. So, I think it is quite a precarious position to have it as a temporary use. Because you can be moved on, you can lose the right to grow produce there. But if you have got a good business plan, then it can be permanent. I know some kind of farming examples on mushroom farming that has changed the policy. They were selling mushrooms to local restaurants. And they found that even though they were selling that in boxes they moved out to actually drying the mushrooms as a more profitable focus.

If you are looking at growing underground in London, they are really hard known business people. I think the limitations come with that type of farming is the type of product that you could produce. Where is their doing leafy vegs? A lot of urban farms which I saw they tend to grow leafy vegs and then some grow tomatoes using hydroponics as well. Another veg is not as easy using this kind of systems. But for me, the technology will change and improve. Things that may be grown are baby vegs. So, it is viable if you have got a good business plan and then potentially it could be long term.

I think people do not do hydroponics well. The once that are doing hydroponics well, for instance, Growing Underground do it well. Grow Up do it well. In Portsmouth, there are actually two big aquaponic farms. The problem with aquaponics is that they have to maintain the PH balance of water. But what is nice about aquaponics is the closed-loop system. And they can sell on fish. Growing underground are located in the middle of London and that makes them even more profitable and successful. It is not that is it impossible here.

If you think about the whole kind of change in the food industry, you have got a big shift. There is vegetarian and vegan food. So, there is a shift in society in terms of what they eat and how they eat. And I think it is the start of the food revolution.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 7: You need to get planning permission for the change of use. So, changing it from a car park for something that has a commercial purpose. You will need to apply for a change of use. And Therefore, I would suggest starting negotiations with the local authority from an early stage of the research to see if this would be actually feasible in terms of what are the planning policy. Check the planning policy as well to see how committed the local authority are and then fortunately sometimes their document, like the sustainability document or any document; they look a little bit fake. They are written in political speaks, and often do not provide practical guidance. It is also good to know the people to have conversations with. I suppose planning is also about the visual look of the building. I think it is difficult to improve a car park so depending on what is required for that adaptive reuse I can imagine that it would be detrimental to improve the look of the car park. And it all depends on how you handle it.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA?

Interviewee 7: I think there might be a misunderstanding among local authorities about getting the product in and out because they might see that as the need for lots of vehicles. And they should not see that in planning terms, it is a transport issue that would have affect planning. I do not see it as a potential problem, and this is when negotiations with the local authority are important. By having a conversation with them would be better. You could also engage in public consultations because if you have public on board that would make planning issues a lot easier.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 7: I think adaptive reuse is possible eventually in every building when it gets redundant. It is just whether or not they see it as a viable thing so, in a way, it is not their role to look at your kind of a business plan. That is for you as a developer or whomever, it is to know whether it is a viable thing. They concern with planning issues, and planning issues would be about movement in and around building, the look and feeling the building, the change of use of the building and maybe the impact on the local community. Involving the local community would be good because it would be what the impact would be not that they always look at. Anything that has a positive impact on the community will be beneficial. And I would see urban farming as a positive impact. I would see perhaps any adaptive reuse, which has got any financial viability, has been positive.

Interviewer: What are the key architectural opportunities for the adaptive reuse of an inner-city multi-storey car-parking structure for CEA installations?

Interviewee 7: As a human, you get out of your car and walk around, so the height limitation is adequate for human occupation. And if you think about Growing Underground, they have a lot of these hydroponic systems stacked and all they need really are water and electricity. So, you have got electricity in car parks. And it is whether or not there is decent water supply. So, I think the water supply may be a limitation. I do not know how they clean car parks. What I think you could probably do is rainwater harvesting, you could do it easily on the roof. If the structure would allow it, you could even plant the top of it like in Brooklyn Grange. So, you could have plants on top and you could be growing carrots and onions and all of that in planters which you could place there. And underneath, so in the actual car park, you could have a mix of vegs.

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 7: The height of the space may be a limitation. People like high spaces generally. From an architect`s point of view, the floor-to-floor height may be too low, but it depends on the type of business and on the type of space they need. And it depends on how you design it and how you let the lighting. So, I think there are quite a few businesses run there. I also think that some people may like that kind of a concrete structure and you may want to design it as a kind of industrial space. It is actually trendy right now.

Interviewer: Which architectural modifications should be applied during the design process of the adaptive reuse of inner-city car-parking structures for CEA in order to address the opportunities and limitations of such an up-cycling?

Interviewee 7: You should think about what you want to have these. For instance, a business involved in graphic design as well could have a little kind of office up there. Because the farmers are going to sell and promote the product. So, it could be almost as a small business unit. And printers, people would print posters and leaflets there. Engagement with the university would be useful as well. You could have business incubators. And it is actually always about the right people. On sustainable communities which exists, what is actually interesting on sustainable development, what you actually find is that there is a specific type of person that chooses to live in that type of environment. So, it would naturally encourage a specific type of person. And that is because it is a belief system.

Interviewer: Would you consider the adaptive reuse of the inner-city multi-storey car-parking structure as a value in terms of environmental sustainability?

Interviewee 7: Yes, I would. Using any kind of alternative power source is a possibility. So how much you need to keep it going. And involving the community is critical. In Brooklyn Grange, they have got PV panels and that keeps them going. I know many allotments have PV panels. It also depends on how many they need and what sort of power source they need.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 7: There could be some alternative methods of energy production. Would it be viable to have a ground sourced heat pump? It depends on how the basement looks like in the car park. You could drill down and install the heat pump. That would be much better. And you could green the sides of the car park in the way that they could produce vegetation as well. You could have panels on the side of that. I would not advocate algae because that produce very little electricity and that stinks. You could create the synergies with the local community, especially in the case of the car park where the housing is located on the rooftop. The biggest example is in Hong Kong, where people adapted the roofs of buildings to live there. So, the symbiotic relationship is possible. People can live on the rooftop you could have small businesses there. So, there is a lot of possibilities.

Interview 8

Interviewer: Would you consider the adaptive reuse of inner-city car parking structures as a value or benefit for urban sustainability?

Interviewee 8: Yes, definitely. As a practising architect, I have been working on the design of the car park in Italy. One of the things that we try to analyse as much as it is possible is the span of life of the parking lot. In Italy, we are working on the project of a multi-storey car park and the main point is how we can design them to make it possible to convert them for alternative use in the future when we do not use car-parking structures anymore. This is my hope that we will not need them one day. We are expecting that we will not use the inner-city car parks in the future because, for example, we expect to use more public transport and so on. So, for example, one of the points for the construction of the car park is the floor-to-floor height that needs to be higher for many uses than the standard height for car parks. The other aspects are related to embodied energy. The idea of renovating and reusing instead of demolishing is highly relevant. Also, demolishing, especially reinforced concrete and redeveloping a new building is a significant issue that produces vast amounts of CO2. So, this is a key aspect.

The second reason why I consider the proposed adaptive reuse as a significant contribution to urban sustainability is related to the project which I currently work on in collaboration with the City Council. The project is about the use of vertical green, not for food production or screening but mostly for air pollution mitigation.

Interviewer: Do you plan to implement the project in the inner-city area?

Interviewee 8: Well, we do not focus on the multi-storey car park, although I think that would make a lot of sense, we focus on school architecture. We have decided to focus on a school because children are the most fragile part of the urban population and air pollution is affecting them seriously. So, we want to use a neglected part of an existing school to build a vertical green. So, it is very close to what you are doing from the perspective of the improvement of air quality or air pollution mitigation. So, I think that this is a perfect combination to combine the idea of vertical greening with the multi-storey car park because they contribute to the air pollution in the inner-city area.

But when we talk about the adaptive reuse, the point is to conduct the life cycle assessment to analyse which strategy- the demolition and the redevelopment of the site or the adaptive reuse will be more beneficial for the urban sustainability. So, you cannot say that it will be better to demolish the structure or to reuse it, but you have to develop the scenario for the future and compare it to the alternative scenario. Based on such life cycle assessments, you could give the answer. For instance, the majority of amphitheatres build in Italy in the past for gladiators` fights etc., are today still there because they were and still are used for alternative uses such as marketplaces, opera performances, so why the parking structures should not be used in a similar way.

Interviewer: Do you think that the adaptive reuse of inner-city car parking structures for urban farming could be permanent?

Interviewee 8: Urban farming in the city should be a long-term strategy. There is the author called Johnatan Foley, who is a famous American agronomist, he has written many articles and books and one of them is a solution for a cultivated planet. One of the conclusions of his research is that there is not enough land to feed the future population and for that reason, we have to develop vertical farming in the future to survive. We are also going to face more compact cities so in this context, generally urban farming should be developed as a permanent activity.

Interviewer: From the architect`s point of view which may be the key planning limitations for the adaptive reuse of inner-city multi-storey car parking structures for urban farming?

Interviewee 8: For urban farming, you have fewer limitations than for any other typology. I do not see any limitations for farming here. There would be more limitations to implementing other uses. There is a system called Hydro membrane, which is a Japanese technology but it is a foil on which plants grow.

Interviewer: Could you think about any other elements which should be installed in car-parking structures to convert them for technologically advanced urban farms?

Interviewee 8: I am not for monofunctional buildings. So, I assume that urban farming as the adaptive reuse of car parks should also be mixed with some other uses. If it was totally monofunctional, the first thing is the pink light. So, the traditional pink light system should be something that should be considered so sensors that allow a different gradient of lighting the more you need lighting. If you could use the external lighting, you can install sensors and lighting system, so depending on the distance from the external lighting, the sensors can control the homogeneity of light and regulate the light. You also need to think about fire protection, so if urban farming has a high fire load. My guess is that you are not going to have any problem with the fire regulations, but you need to check that.

Interviewer: Could you think about any sustainable technologies that may be implemented to reduce the environmental impact of the development?

Interviewee 8: There are obvious things like you can use biomass waste. I have a few more ideas. The first is that you could collect the rainwater from the rooftop and use it as a battery which collects energy from the photovoltaic panels. In the case of Portsmouth, at least 25 percent of the energy produced using PV panels must be stored during a different period. This means a lot of batteries, which generates costs because the batteries cost a lot. So, if you take your parking and you put photovoltaic, you have to store 25% of the energy which you produce. If you install a water tank in a roof and a water tank in a basement then you collect the water on the roof and then you use your water for the farm and then it goes to the basement and every time you generate the energy with the photovoltaic then instead of putting the battery to the photovoltaic you use the pump to bring the water up to the water tank on the roof of the building. This means that each time you use the tap to bring the water up you can use the energy which you have collected by PV panels. This system makes PV panel more reasonable in countries like the UK, where there is not so much sun as in the equator.

Interviewer: Are there any other technologies that could be implemented?

Interviewee 8: Yes, we have done research together with Steffen Lehmann and we developed a Wind Assure system. Wind turbine system does not work very well with the low-speed wind and if there is a high-speed wind the turbines vibrate and they are noisy and they do not work very well in urban settings. These are the two issues that are relevant in UK cities. I have done many projects to examine how to avoid these issues in cities. With Steffen, researchers from ETH Zurich and the University of Southampton, we have done the architectural study on this innovative system that is called Wind Assure. We have patented the system; we are still testing it; it will be super effective. Basically, it is a heolic system which does not use any turbine. So when using this system, the wind can be low-speed and the energy is produced without any vibration problems. We have worked with the existing car-parking structure during our research. We wanted to cover the existing car park with the modules that produce the energy. The modules do not have to be attached to the façade; they can be installed independently, on the ground level or in the rooftop. They can also be a part of a small architecture in the city. They can have any dimensions. They need a little bit of space on the front and back to catch the wind.

Interviewer: Is the system already installed somewhere?

Interviewee 8: I do not think so. You can contact them and I am sure they will be super happy to work with you. The system could be very supportive of your project.

Interviewer: Do you think that it will be possible to install PV panels and wind assure system or is one technology enough?

Interviewee 8: I would say that it very much depends on the design. I would not say that one is enough; it depends on the design. It is much about how you could optimise the energy. Probably, photovoltaic will be more productive, but there are areas where photovoltaic are less efficient because there is not enough solar radiation. But often, in places where there is not enough solar radiation, there is higher wind speed and in cities, it is often impossible to build wind turbines because of the noise pollution so you could then consider the use of wind assure system in combination with the PV panels. But that must be considered according to the site-specificity. Climate analysis should be conducted before the decision is made.

Interviewer: Which synergies could be developed between the urban farm and additional uses such as housing to developed synergies?

Interviewee 8: If there is a chance to develop an urban farm with other uses as a multifunctional architecture that would be the most beneficial solution. The idea of the compact city considers mixed-use development as a priority. Urban farming should be not only concentrated on food production but also on improving other aspects of peoples` lives. One of the aspects is the reduction of food miles.

Interview 9

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain? Would you think of this as a permanent or temporary use?

Interviewee 9: It is interesting that you are researching the car parks. We have just been in contact with a little star-tup and they also want to reuse a multi-storey car park for farming. They are focusing on car parks in shopping centres. They say because shopping centres need to develop strategies to revitalise their business model this could be a beneficial strategy. One student of ours is also working on this issue. I see the point when you say that in the nearest future or even now they are not used any more to that degree that they have been used.

On the other hand, I am also involved a lot with the mobility issues and everybody is wondering how can we get cars out of the streets and make the street space more car-free. And there is one thing about the existing car parks, where you need cooperation with the owners or city councils because that are private car parks and so on. On the other hand, I think they maybe even used again, much more often than now. But there is no proof for this theory; there are just discussions going on.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA

Interviewee 9: Concerning limitations, the main issues is to convince the owners to use the building for farming. And it does not matter if this is a car park or any other building. I think this is the main challenge and then, of course, you have got a lot of regulatory issues, planning, zoning and fire regulations. And it strongly depends on the type of farming you want to implement.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures?

If you develop something that is accessible, that offers something that raises the quality of life, for example when you think about the combination with the housing; then I guess the acceptance would be higher than in the case of high-tech, enclosed agriculture. I think it is a good opportunity to develop a mix of uses. When you think of an enclosed farming system one potential do it inside the city is that you could do that in a way that will connect the resource loops. I think that this is a big potential and if you plan to have a mixed-use building then it could be designed in a way that allows to use for example the waste heat from the area to heat the farm and the other way around and that you connect the water loops and you could use the greywater clean it up and use it for the farm or things like that. Single projects are practising this already and I think this is enormous potential. Another interesting idea is to develop Food Hubs. So, when you have a rooftop greenhouse and indoor farm inside and then you have other food processing businesses in this building. You could have synergies of not only different uses but also other businesses developed around that food production. You could have a marketplace.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 9: My opinion is you have to really think about what goal do I want to reach, what is the purpose of this farm? Is it for the people, is it for food production and so on? The place where you want to build the farm also depends on that and how do you build it. I think that acceptance is higher when if you do a social project, not a purely commercial project. On the other hand, when you run a social project, it is usually an open farm, not hydroponic farm. There are approaches to use technologically advanced projects mainly for educational purposes. But then it is about social issues, quality of life, social exchange, education, empowerment when it is connected to some training activities. It could also be a secondary food source for more impoverished communities.

On the other hand, purely commercial farming could also be reasonable if it makes sense in a particular urban setting. But both ways are not for supplying the large population with food. Because usually, the farms grow lettuce, leafy greens or herbs. So, this is nothing that really feeds you. If you look at Lufa Farms, they grow other stuff too, other vegetables. They also have interesting cooperations with rural farmers from the region which is also a good initiative. They know they need other stuff to offer a broader range of products, so it also strengthens rural farmers. But I think that the acceptance will be higher for social and educational projects in any case.

Interviewer: What are the key architectural opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 9: Well, in my mind, I always thought about the rooftop which may be transformed to the farm by for example developing a greenhouse. If you want to include lower parts, it only makes sense when you enclose the space. This means you would need lighting. So on the rooftop, you could have a greenhouse or an open garden and in the lower parts, you should think again about the purpose of the lower part. Would that really be a social thing? Would that really be about improving the quality of life? I would see that much.

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 9: All the weight issues. You would think that when you have a car park you do not have to think about the weight issues but we have a project here in Berlin and it depends on how the load is located if it is a constant load or is it located on the whole area. They also had problems with fire regulations because there are different regulations when people just go the car and leave and if they stay there longer. You have to think about water or lighting. You have to think about space for packaging, deliveries, logistics. Energy generation will also be important. So, for example, photovoltaic.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure (name of the car-parking structure) for CEA installations?

Interviewee 9: There are many potential technologies, but the problem is that the infrastructure may not fit together. Many developers of farming projects have told us that they had many good ideas about how they could improve the sustainability of their projects, but they could not implement them or reduce them because that would be too expensive or impossible to implement the ideas. But we have a project here called roof water farm and it is about using grey and black water from housing block for farming. It is not in a roof, but they plan to put the greenhouse on the rooftop. They grow with hydroponics, they clean up all the grey and black water from housing and direct it to the fish tank and fish nourish the water and then the typical aquaponic system continues and it works so there is a proof that you can do it and it is just a thing of will of the developers or in the case of existing buildings of the owner of the building. There are also issues connected to the infrastructure, money and so on.

If you think about your idea about the hotel, there are already hotels that have productive gardens. It is all about the idea, what do I want to produce and how much do I want to produce. So if I want to grow something that I can use in the hotel kitchen for example and I want to offer a place where guests could sit and rest. You could put some small rise beds on the rooftop and create a nice calm place. Then the only synergy may be composting, which could be done easily because everything is in one hand, so the operator of the hotel kitchen is also the operator of the hotel garden. You may then arrange it with the water and this is not a real social thing. According to our typology, it will be more about creating the image of the place.

If you want to do business or if you want to cooperate with the farming business the way I would also farm in a hotel would be completely different. It would be an enclosed greenhouse created to maximise yields; it could be combined with the photovoltaic and other systems to produce solar energy. So it is a general decision on how that should look like and what is the purpose of the farm. And also how it is operated.

Interview 10, 11

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 10: I think little about that technology is known at the moment, but I know it is growing. And I think it is difficult…there is so many different agendas, even the one key agenda which we are trying to promote is green infrastructure, which is one of our key priority areas. It has been quite challenging to say how it could be implemented, trying to overcome things, concerns and nervousness about the maintenance of green infrastructure. So, there is still a strong perception, especially in that level of the local authority, that green infrastructure equates to high maintenance costs. And green infrastructure could actually reduce maintenance costs or contribute to the public health agenda in a strong way through improving the public realm, perhaps reduce crime rates, reduce litter and add positive benefits.

And food growing is a part of that, but I think having less awareness, less experience and knowledge expertise in that creates a bit of a barrier to progressing and implementing green infrastructure projects across the city. We have had two successful sustainable green infrastructure and the benefits of that are for example the rainwater capture in periods of heavy rainfall and an impact and benefits it has in terms of reducing an impact of heavy rain in the local residential area. So I think in terms of hydroponics and practical example like that somewhere in the city would be very useful to help demonstrate benefits. But that the case with anywhere, any local authority.

When we are talking about urban regeneration, what is really important is the local community engagement- it is about bringing the community and local residents with you on anything that you are doing in their neighbourhood and street where they live. So, what does hydroponics mean or hydroponics project means to local people? Why would you want to have it in your doorstep? So making something like that means local people have to be involved in that.

Interviewer: Would you think of CEA as a permanent or temporary use of the London Road Car Park?

Interviewee 11: Could be both. Temporary, it allows more flexibility to be redeveloped in the future, a maybe a higher value of more necessarily use or whatever your priorities are, social housing for example. Or if you have got space and there is a demand for that type of infrastructure maybe there is a permanent opportunity.

Interviewee 10: Yes, and through the circular economy discussion that we were having that bring up these opportunities on how we can better think about innovatively using our spaces. So, you know this idea for pop-up shops in retail, empty high street retail shops where you only need to use the space for a period of time. So, if there was some kind of technology that could be easily constructed and destructed for a short period of time that could work perfectly for that car park.

Interviewee 11: I think that for an initial thing as it is experimental and new to have it only on a temporary basis would be quite a good thing. Because if you do not like it or it does not work we are only doing it for this time to prove the concept. And then if this is demonstrated maybe, it can turn to be permanent. It is probably the best strategy to try to introduce this idea.

Interviewee 10: Yes, definitely. And then landlords may be a little bit less nervous about that permanent thing going on in their building. So, that gives flexibility and make more projects happened potentially.

Interviewee 11: There is a lot of artistic groups in the neighbourhood that use temporary spaces. Spaces that were abandoned, industrial sites and that sort of things. And then they get redeveloped.

Interviewee 10: Also in a seafront, it would be quite nice to have that on a specific time a year. Or using spaces that are used during the summer and then not used during the winter. So how they can be better used.

Interviewee 11: That can be something for a season tourist economy.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car parking structures for CEA in Brighton & Hove?

Interviewee 10: I do not personally know what the long-term plans are for the car park. It really depends on the plans for the car park, whether it is unutilised whenever it can be put in better use.

Interviewee 11: I do not know a lot about hydroponics.

Interviewee 10: Yes, exactly. Which is the point I try to make. A little knowledge and expertise in a local authority in hydroponics. So, you would need a kind of pilot project.

Interviewee 11: A Food Partnership has thought about that on the event when Steffen Lehmann came to the one we did on the natural environment and green infrastructure. There was one about food as well, which introduces these ideas of vertical systems. I mean it is like science fiction for me. That was the first time I come across that sort of idea.

Interviewee 10: Another thing is that there is always a shortage of allotments growing spaces in the city. And especially in that area where you have pointed. It is a high densely populated. There is a new apartment block and there will be more developed around the Brighton Train Station so it would be a good place for food growing. Local residents can use it.

Interviewee 11: We have allotments on one of the new development in Brighton. It is a sort of echo flats with rooftop allotments. The building is just the opposite of the London Road Car Park.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA?

Interviewee 11: You talk about 'defunct' car parks, and the Brighton example you give is London Rd. This is definitely not defunct at the current time and I am not sure what the likely short-term scenario would be in which it was defunct: it is a city centre site, close to the station and to a major shopping area in a city that regularly has too few parking spaces to meet demand.

Car parks are very a significant source of income for their owners (in this case, the city council). It, therefore, seems likely that the council would seek to maximise revenue from a defunct car park, either in terms of its capital value (i.e. selling to a developer) or as a long-term resource (e.g. renovating it as retail/storage/office space for rent). I am not sure how much revenue hydroponic farming is likely to produce? While I can see that it might be a social good, social value would only be one consideration in terms of land disposal.

If defunct, London Rd car park would present a potential development asset as it is a relatively large site in the city centre with good road access etc. At the current time, the most obvious use for such an asset is to develop it as housing, with an affordable housing element. This is likely to produce more short-term social value than urban farming because the lack of housing is considered a more pressing problem than local food sustainability. This may obviously change in time, but I would expect the current planning policy to focus on the current need.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 10: You know, one of the things we want to push forward is this all concept of the circular economy. And that touches upon very much — reuse of, not just materials and space but things like energy as well.

Interviewee 11: The area where the London Road Car Park is located is actually developing. I went to the exercise where this area was one of the case studies that they use. They were thinking there how we can implement more commercial uses and pedestrianised the area. So, it is quite a good area to select.

Interviewee 10: On the personal level, I know that the London Road Car Park is definitely underutilised most of the time. If you look at it and if you have visited the site, it can really benefit from the lift as well.

Interviewee 11: You would need the element of community growing and new community activity in Brighton. So, it would not be a solely commercial place for food growing. You need that grassroots and community dimension there.

Interviewee 10: In order to be successful, I cannot imagine an independent university-led farm being able to exist without the residents, they must benefit someway.

Interviewee 11: And politically, you may have more support for that when you involve the community that when it would be a purely commercial development.

Interviewee 10: Yes, definitely. And any further opportunities that are one of those things that other projects where the Food Partnership are involved in are a community composting scheme. There are schools locally who could benefit. There is Sainsbury`s in the neighbourhood so how that could benefit that particular Sainsbury`s?

Interviewee 11: There are lots of start-up businesses in New Eldon House which is next door, which is the Council building.

Interviewee 10: It has been regenerated as well. I mean the common part.

Interviewee 11: There are technical start-ups and art spaces as well. So, there is quite a lot going there in this interesting location.

Interviewee 10: There are sports fields on the rooftop of the car park, which are used by the school. So, the children could be involved in growing in there. St Barnaba`s school do not have good outside spaces. So, it would be great to be able to offer that as an additional resource for the school not only as a green space.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 11: So, you need light, you also need water. Water is one of the things we do focus on. So, the flood risk and sustainable greywater use for green infrastructure. I was looking at the green infrastructure as a part of a biodiversity roles flood prevention. Yeah, so there can be some win-win potentially. Because you need water, you may harvest the water; it may be polluted when it comes from the roof of a garage.

Interviewee 10: Yes, water capture.

Interviewee 11: The Food Partnership is always looking for a new sort of growing space for allotments or community gardens or urban plots. I am always up for gaining as many things as possible in one place, but it is not always possible. There is always a potential conflict between different agendas if it is ecology or food growing or water management or whatever. To some extent, they can integrate but you cannot have everything in one place. So, this is always a problem with the green infrastructure, you want to have everything, but you have to spread it across in order to make that happen. So, yeah, we have ideas but no detailed plan. There is no green infrastructure strategy in Brighton & Hove.

Interviewee 10: We participated in Horizon 2020. Our application was focused on the creation of the green infrastructure plan for the city, focusing specifically within the context of that project on a quite a bit poor neighbourhood in the centre of the city, not here but further down south. And which role the green infrastructure could play in lifting that neighbourhood in terms of reducing crime rates, how it supports public health, how it could offer people space which they currently do not have. How it could improve the impact of climate change and reduce floodings. All of those things that green infrastructure could have on such a neighbourhood which is currently quite grey. And we are using that as a pilot so then we can build upon a wider development within the city, which is still something that we would like to do.

Interviewer: What are the key environmental limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee 11: If you grow indoors, then there is the increased energy demand. But LED is low energy and you can put solar panels on the roof to supply that.

Interviewee 10: And it is linked somehow to the energy agenda because we deal with the energy at the moment.

Interviewee 11: Sustainable drainage scheme (SADS), the solar panels I think to have a closed-loop for the energy supply, especially if you use the LED lighting for the growth.

Interviewee 10: Green walls.

Interviewee 11: Yes, could be. You could have biodiversity features around it because you could have companion planting for your pest species that also have biodiversity benefits. How do you plan to grow? Is it open to the air and to pollinators? Because pollinators are a big thing… An open farm would be desirable but the food you would growing need to be connected with flowers to attract the bees and for require pollination for fertilisation. So, if it does not require that when you grow weed for example, then it is wind pollinated and it does not need bees. But we need bees for cherries and apples and other things and many food crops require pollination. So, if there is a pollination element, then there is a biodiversity dimension.

Interviewee 10: A lot of these new ways of agriculture is through this greenhouse system. I think this technology is used a lot more indoor. I went to the circular economy conference this year and this way of using spaces was mentioned and how Amsterdam is developing its agenda for developing more green roofs and hydroponics came up.

Interview 12

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 12: The London Road Car Park in Brighton & Hove is a sort of dry, a sort of brutalist kind of building so the question how you could soften it by for instance converting part of the ground for having shops or a kind of unit offices and then a kind of green yard. There is also this thing about intensifying the site. Some people think that there is a scope for go on top of it, demolish it and then build something completely new to add to what is there, that is another thing. Or to just convert a little bit. Because there is also this connection through York Hill on the site, so the question is how you can make that a bit more user-friendly for disabled people. Because at the moment there is this staircase and it is not very useful for cyclists, disabled people, people with any mobility issues. So there is this thing how you could change that space or how do you change the design of that to allow that link to be more accessible and more used. So, there would have been an impact on whatever you do there; there would be an impact on the site. You might want to consider that. If you want to consider, you know, a sort of, how you might develop hydroponics. You might want to think about what happens below and what happens beneath. So, there are many possibilities. At the moment I am aware of the number of people trying to do different things, but it is within the range which I have just said.

Interviewer: What are the key planning limitations for the adaptive reuse of the London Road Car Park for CEA?

Interviewee 12: One of the difficulties in that building is because there is an area where the houses are, but the other half is actually a school playground. And that is something that you need to consider as well. Some people may say: Oh, we might relocate that or just try to redesign the school to have that closer or to continue having it but then how you perhaps make it more accessible or less dry. But when talking about hydroponics, you could create a new incasing for the whole thing, which is, you know hydroponics could be located in that volume. But you know, there is a lot sort of things that you need to do. One thing that you need to be aware of is that there is a listed building next door. So that is another fact. But again the back façade is not as important as the front side. So, coming back to the opportunities, the back you may have a bit more flexible way in terms of what you might want to do because it may not sort of impede the view. So, yes, it is a good site to choose because you can put there a number of things. It is whether the best use is made of that. Because you know, as you have said, it is a very solid base whether you can actually go on top or whether you could actually build an independent structure there where the structure is. So, this would be a flexible layout. It is a huge car park. This is a car park which was designed at that time when there was a lot of space. For instance, the floor to ceiling height is very big, and then you think well cars are not that high. When you look at underground car parks, they cost a lot of money so the floor-to-floor height is much lower there. So there is this thing whether there is a financial case to demolish the car park and start again or whether this is a matter of just adapting something.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 12: The only thing that I would encourage you to consider is what the masterplan says or what are its aspirations for the place, you know for the bottom- Providence Place. So, you know, you can actually create attractive frontages or you could even have housing there- if there is enough height to have like Massenet's. So, it could be that the active frontages, housing or some creative space or a mix of uses. And then, you know, that is what the plan is saying and the others thing is the link in your uses, so how would this link be implemented or designed and what can we do because there is this huge change in height. So how can the car park be integrated? So, I think there is a lot that could be done. You just have to think about the aspirations of the masterplan, then the heritage issue, apart from that- the world is yours in terms of what you can do there. Because you do not have financial restrictions. If you are thinking about putting forward a financial assessment, then that might inform. If you do not put one thing but consider a number of options then the various scenarios will have different financial implications. And that can be another thing. The ideas will never be going to be wasted. It might be that people do not use them. But many concepts are developed, then it takes a while to sink in and people accept and adapt them. So it could be that people consider the outline the massing the height that you are proposing. They could consider the hydroponic element.

I think that if it were just hydroponics, it would be less attractive then when there was a mix of developed uses which are making money, some of which providing community facilities and some of which have the environmental dimension. but even if you just want to have hydroponics, you could create a volume. You could just have a massing. you know like something cased in hydroponics would look like and that also offers value. And it would be good for sustainability because you get local people being able to access allotments and other food-growing places. So they will not have to travel to the outer areas where the allotments currently are. So there is potential if you build a volume as Paula says.

Interviewer: Would you think of this as a permanent or temporary use?

Interviewee 12: Well, it depends. I think if you are just thinking about hydroponics then you could think about a sort of external structure. You will need specific funding for it. If you are not generating income, then you could cross-subsidise. Then you will have to think about how do you fund this. Yeah, would people pay for a vertical allotment? I do not know. However, I do think that converting that car park, I do not know what the cost would be of converting it and we have not done any sort of financial viability assessment of any of these options.

So in many cases, you need a sort of more detailed design to be able to assess the financial viability assessment. So, it is something that we are open to proposals. If you want it to be permanent, I think you should go for a much higher value-generating sort of proposal. So, you could knock it down and rebuild to generate more income than the car park. But it also could be that if you think that you do not want to go this far then there might be areas which could be converted and then see how much that works. That might be something that works for the next three decades and then redevelopment comes after that. It is very difficult to predict how things are going to be like. I think you need to make your assumptions.

Interview 13

Interviewer: Would you think of the adaptive reuse of inner-city car parking structures for CEA as a permanent or temporary use?

Interviewee 13: You are more likely to get a meanwhile sort of uses. And you may set up businesses that are movable, like containers that can be shifted because it is a big car park, so it has a potential for other large-scale developments.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA

Interviewee 13: I think it is difficult if they see there is an income source with something else. You can try to build your argument around increasing access to healthy and sustainable food. You can link that to different agendas around health regeneration or obesity, food poverty. You know looking on supporting local food production and sustainability of food growing. But it is not going to be a priority for the Council and those agendas. It is easier for them to support existing food growing projects or to work with allotments or other projects that do not involve a lot of investments. It also depends on the local authorities. Several local authorities started to be more proactive in having more sustainable food growing strategies. You need to look at the existing strategies of the local authority like the Local Plan or the Core Strategy or looking at the health and well-being strategies. And it has got a written in a sort of strategic level that would support the argument around increasing access to healthy and affordable food investments or whether it is about reducing the distance which the food is travelled, you know, the journey of food, or is it about the sustainable way of it is produced itself. So, you would have to try and see what the overlap was for what you are trying to achieve. There are different strategic documents of the local authority.

I know it is happening in some places. So, I guess it depends on what the alternative uses are for the car parks. If they have got other opportunities to make vast amounts of money. If it is a sort of redundant building, they might be that you get a sort of a meanwhile deal, which is where they have got a plan for it in the future, but they have not got an immediate use for it. So, they might give you some short time agreement. But then there will be a question if people who run their businesses would like to invest in something that is an only short-term and what the capacity is to do that and what the limitations are around that. It will depend on local circumstances around that particular car park. It will also depend on the specific side. I mean if there is a potential for massive housing development, then the council, of course, will go with that a food grooving initiative.

I am trying to think about a specific campaign. With food cities, we run a national campaign, we try to refer to a type of a general agenda. We have one in veg cities, that was a classic one. It is about the increase in the current uptake of vegetables. So, again that can be across the whole spectrum: increasing school meals, increasing the number of veg menus in the private sector, catering outlet. That would include some additional supporting vegetable growing within cities that mean community food gardens and looking at markets and things like that. There will be a whole range of different activities around food growing. What you are talking about is quite specific which is a sort of niche thing, it is not really the mainstream regarding how much you can contribute to the agenda. But it would not be a priority for a city.

The project may be more around the research. I am currently involved in an academic project which is called FOOD-WATER-ENERGY NEXUS where they are looking at circular economies so where the waste from one product can become an input for another. They are looking for hydroponics and hydroponics. Especially how waste is circulating in the system, that is a very interesting area for academics at the moment. I think they are looking at the potential and how it can be scaled-up either in different cities, in modules or at a different scale. So, it is starting to become something of interest because it is very resource-efficient.

It is an interaction between food, waste and energy and how waste products circulate to become an input for another organisation. There are sort of initiatives starting to look at that. It is coming from the waste agenda and circular economy. There are quite a few initiatives that have that in mind now I think and that is a quite interesting niche, sort of like a new area of the economy. It is a new sort of angle that a lot of enterprises are taking and there is an increasing interest I would say amongst a certain group of enterprises. The question is how long that can work and what the limitations are. You know the business can expand and then the circumstances change so how can it be sustained. But I know it is an area of interests. So, I think it may be more about academic development and sustainability and the waste agenda. That may be a better way in.

Interviewer: What are the key planning limitations for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 13: I am sure that you know there is so much pressure on land in urban areas for housing developments and things. You need to look at that specific local authority and what are their absolute priorities define in the local plan (land use, change of use) and what they mainly support. You might need to look on a case by case to see exactly what their priorities are.

The driver for local authorities is also an economic development so if you look at the new business start-ups and job creation and that whole agenda… In Bristol, there are quite a few of these places with start-ups which are linked to food and I am sure that is welcomed by economic development within the city. So, innovation maybe another angle. That maybe even more of interest than health angle. Regarding health impact, the small start-up growing salad crops is not that great. They tend to grow high-value herbs and salads for restaurants. So, economic development may be the right argument.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 13: One of the angles of this that may be a link to that is that there are supplementary planning documents that get written in various cities which are specifically about housing which consider food growing spaces within planning applications. It was a sort of supplementary document which encourages planners to consider in their planning application all the potential food growing spaces. If you are a developer and you want to build a housing development or mixed-use development, you have to consider food growing spaces in your application. So, the supplementary planning documents are really to advise planners on how to assess farming applications coming through. If the local authority adopts the supplementary planning document, it gets communicated to potential developers. Then they know that that is going to be a factor in their decision. They might then work towards the increasing demand for food growing spaces in their proposals. So that types of things may be a way in. You may have a look at those. It is really how you can influence the planning decision to develop a proposal.

You could focus on obesity, increasing access to affordable and healthy food. It depends if that will be private enterprises or owned by the council. When you look at hydroponics and aquaponics, it is more like a small-scale business. It is not really community accessible. So, you could show the educational side and the consumption side. It depends on the food growing side. Because really if you are talking about salad crops when you think about the number of calories which they are actually providing for a city, it is minuscule for what is required regarding health or access to fresh food. It is a difficult argument to make I guess. What we are finding at the moment is that the main forces behind sustainable food agenda are health. I am looking at food poverty at the moment and food and health inequalities, malnutrition as well as obesity. It is a difficult one to link to a particular sort of aquaponics or hydroponics or that type of development. It is more around a sort of large-scale shifts in access to fresh food and school dinners or possible catering and things like that. So, it is more about shifting the whole industry towards increasing vegetable intake.

The main value of the community food growing is the community engagement; they work with a lot of people who are quite marginalised in society so people with disabilities and difficulties, children with different needs and people like that. So, one of the main values is not only the food that is produced it is more the educational side, social inclusion, it is a sort of community engagement agenda as well as educational awareness. The whole argument around increasing peoples` connection with the land where food comes from and the knowledge, the understanding the food is produced. It is not so much about the quantity of the food that is coming. The amount of food that is produced by community food projects is generally small. So, the interest of the local authority around that is more around social inclusion and engagement I would say rather than health regarding nutrition. It is more health regarding mental health.

It also depends on what the alternative uses. There can also be arguments around biodiversity improvement, keeping green spaces. It depends what else is proposed for the adaptive reuse of this site.

Interview 14:

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 14: In Bristol, we have done a lot to enhance the inner-city rooftop gardens or vertical gardens as options. So far, we did not have any proposals to test the building-based farming. We have four city farms. Two of them are quite innovative; they offer education.

It is important to be clear which type of urban farming do you mean. Is it an urban commercial farming, in-soil farming or building-based farming because the costs and benefits are entirely different. Bristol has a lot of interests; we have a network of Bristol Food Producers and what makes it really hard is profit margins. So, discussions are going on how to develop more collaborative marketing, maybe a Bristol grown brand of some kind. Because until you have a market and the distribution, you do not have a contribution to the food supply. You can produce and then it can just roots because you cannot sell it or you have to give it away. So, this is about improving the connection between urban farms and consumers mostly through restaurants. If you produce small amounts of food close to the consumer, it is going to be easier, but you still need to have some kind of distribution organisation that can offer to restaurants a range of products. So, this discussion is happening between Bristol food producers. If you had a multi-storey car park urban farm, they might want an outside organisation to help them with the marketing, or maybe they can do it by themselves. But then for the restaurants, there are too many small businesses which offer to sell them some produce and then it makes it difficult for the restaurants to buy from lots of different people all the time.

Interviewer: Would you think of this as a permanent or temporary use?

Interviewee 14: It comes back to who owns the premises. So, if for example, there was a disused multi-storey car park and the council own it, they might give a lease, but they may only make it for a certain amount of time in which case you need to say this is going to be temporary. So, they might give it for five years, for ten or you might be fortunate to get it for twenty of twenty-five years. I would be very surprised to get it for such a long time because of things in the city change. The value of the land is growing so fast that it may be much more profitable for them to sell it for example, for a housing developer. So, the value is the biggest problem that we face right now and for that reason, we try to protect the land for food. So that can mean that projects like Grow Bristol should be able to move. So, they should develop a mobile type of production unit because we think that this is now how urban farming should be developed and everybody needs to be pragmatic about that. I think this is the best pragmatic approach to take. The councils in the UK have been working with the meanwhile leases or meanwhile land use so in the meanwhile before they decide what to do with the site of to rebuild if they can give a meanwhile lease to a community group or a social enterprise. But I think you will not be able to get something like that easily for the car park unless you could demonstrate you could move this is what we are discovering.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 14: The opportunity is to develop anything that creates jobs, anything that provides education, improves health, makes the local neighbourhood more interesting, more profitable, more environmentally friendly. If you are making a proposal, you would have to highlight all of these social benefits for sure. But even then it may be not enough to convince the planner. We did not have any inner-city proposal that would put that to the test. The Bristol Fish Projects and the Grow Bristol, they are the best examples. We try to support organisations like them. Right now, we are taking a very strategic approach. We have got an award for the city, so now Bristol has a silver sustainable city award and so do the Brighton & Hove have. So, both cities are working on gold awards. And that gives us a strategic structure and that is very helpful. We can gather all the people under one organisation because it is not about the work of one farm, but it is about the work of the entire city. So, we focus on more nature-friendly food production, more safeguarding the land, involving more communities on urban farming. We try to work strategically, which means that we need to involve planners, the mayor and the deputy mayor, we have to align our vision about using the good land in the city along with other city strategies. So, it not immediately seen in the work of the Grow Bristol for example, but it is very in the background.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA?

Interviewee 14: For urban farming, in general, the limitations are for competition around the land. I can speak the best about the city of Bristol, so in the UK the local authority is obligated to provide allotments for individuals, but they also have other priorities. The land for allotments is not entirely protected so they can change their mind at any time to move the allotments somewhere else or just reduce them, so it is quite difficult. So, at the moment, we are having a local plan consultation and there has been a campaign to put some pressure on the council to designate some areas to protect them better. In Bristol, some of the best quality lands are located along the main transport routes. So, the risk is that they disappear for new roads, parking and park and ride or new housing. So that is the biggest problem we have.

Interviewer: Which strategy should be applied during the adaptive reuse of inner-city car-parking structures for CEA in order to address planning opportunities and limitations in a way that would contribute to the specific requirements of central areas defined in planning documents?

Interviewee 14: I think it is challenging. There is very little profit in food production businesses so if you want to be in a city, you need to be as productive as you can and also sell for the highest possible costs. When we have these discussions about food security, we are talking about better nutrition, low-cost food, food poverty. These people are not probably going to buy leafy greens. That is not their priority and not for the price which the business needs. So, the business on his own is not seen as a contribution to food security. Certainly not in the short term. If that business is a part of a network of many businesses food between them can produce a lot of volumes, a lot of different type of product. Or if they are also trading with the farmers outside the city then it is easier to make a case for the food security but not until you have got more volume or not until you have got affordable prices. And the leafy greens situation, even the fish it is not a low-cost product. Maybe in the long term and if there is a more product, then it could help. But still, these products are quite specialists, so I think we are coming back to the issue of distribution. So, for me, it is about collaboration. No single urban food production units can do this on its own. They have to be part of a hub or a network or some kind of collaborative initiative.

So, it is essential to diversify the farm. You could do leafy greens, mushroom, you could do some container planting. Obviously, root crops- no point of doing that in a small area, so you need to focus on what works in a small area. You could change the product by seasons and then for engagements. So, I know that Grow Bristol have a lot of visitors actually and this is quite a significant part of their income so you could do that. You could maybe have a café or preparation uses. You could maybe invite schools. There are those sorts of things I think from the research I have been involved in any urban and peri-urban farm just on their own it is really difficult; they have to offer something else either with a network or be very diverse and go more in the education and participatory activities. And that is the way to attract some other funds from the more social sources.

Interview 15

Interviewer: Is the adaptive reuse of the inner-city multi-storey car-parking structures a familiar and acceptable concept within the professional domain?

Interviewee 15: No. However, fresh food is so important and so rare in cities so access to fresh, healthy vegetables is really rare and I know that these buildings that you are thinking about and the vertical farming can deliver food from the farm to the plate in few hours in a city.

Interviewer: Would you think about the proposed adaptive reuse for urban farming as a permanent or temporary use?

Interviewee 15: I think you need to take every opportunity. In the global generation, we had a 64-acre site, they have been moved a number of times around this site as different plots have been purchased for construction. So, they moved around every two-three years. If you have a building that you can use for two years, you should implement the robotics hydroponics which is a huge capital investment but everything in the urban farm needs to be dependable, reusable, to take all the equipment from the one building and put it to the next. So, I don`t think you would matter whether you had a three-year tenancy or thirty-year tenancy. If the business was successful and you had a building, then you would probably end up with purchasing the building and having it for a lifetime. Nothing is permanent. So as long as possible would be great to get stability but I think you could do that anywhere. Look at the guy in a shipping container. So, I think it will be 3-5 years and then anything to that is a bonus. You would have to put a lot of money to adapt the building.

Interviewer: What are the key planning opportunities for the adaptive reuse of the inner-city multi-storey car-parking structures for CEA?

Interviewee 15: I think education is important now. So, it would be ideal for opening that to universities, to children, to schools. To have them coming to grow tomatoes. So, a good idea would be to introduce the community to it. Wherever you are growing, there should be a restaurant. There should be cooking, growing, eating together. These are the basic things but then selling locally or even right there on the premises. I would suggest keeping that all very connected. So, it should be all about the food growing, education, learning, processing and selling and then eating. So, I recommend keeping it all compact. But how many other businesses are connected with food and eating? A lot! There is so much you can do.

I am not surprised that people from the council think that it is very futuristic, but everyone you have spoken to from business is positive about that. It is happening now. In fact, we are even behind the curve now. I think once Councils, cities realise the real health benefits it is enough to fund an invest. And if you add education, eating, processing then why wound not invest.

Interviewer: What are the key planning limitations for the adaptive reuse of inner-city multi-storey car-parking structures for CEA?

Interviewee 15: For some reason, there seem to be planning limitations for everything but going back to the circularity, sustainability and environmental benefits if someone was against that proposal then I think it would be very easy to knock that down if you provide persuasive arguments for the social, environmental and economic development of the city.

Interviewer: Do you consider multi-storey car-parking structures from the modern movement era as an architectural value in inner-cities?

Interviewee 15: Yes, I do. They should be adaptively reused mainly for environmental benefits.

Interviewer: What are the key architectural limitations for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Interviewee: You have to control the internal environment so you would need to wrap the building. Air quality is essential. Once you control the heat, the light and the air to parameters that are good for growing, then all of that can be done. It comes down to the money. But it can be done.

Interviewer: Would you consider the adaptive reuse of the inner-city multi-storey car-parking structure as a value in terms of environmental sustainability?

Interviewee 15: Yes. It is good for the environment and it is good for sustainability. Every city in the world I would imagine have a huge amount of derelict or unused space and as I mentioned before the current food crisis. So, having easy access to fresh food for cities in the future is going to be so important. So, bringing these two together: derelict, unused space and bringing it back into life for the purpose of food production is a crucial concept for urban sustainability. I think it is closed-loop in so many ways. You reduce transportation so sustainability wise it is futureproofed. Every city will require more and more urban farming. There is also a business case for any business to sale. It is a circular economic business. This whole idea about urban vertical farming in a city is 100% circular business. But bear in mind that circular economy is about business, it has been developed by business, for business and it is all about doing your business, sustainable but mainly being profitable. So, it is not a wishy-washy type thing. A lot of businesses, new start-ups, new technologies are making an absolute fortune by doing the right thing, by doing it ethically and responsibly and that urban farming is exactly that.

Interviewer: What are the key environmental opportunities for the adaptive reuse of the inner-city multi-storey car-parking structure for CEA installations?

Do you know about Growing Underground in London? They are a controlled environment farm in a bomb shelter. They use only LED lighting. There is also another company in the Netherlands that works with Philips and uses LED Lighting. The Growing Underground is growing vegetables using computer technology to optimise nutrients, light, everything that they need to control the environment. As a result, the food is of much better quality.

Any waste products for the farm can be used to produce energy. This will be another closed-loop system.

UNIVERSITY of PORTSMOUTH

19th September 2018

Faculty of the Creative and Cultural Industries Ethics Committee

FAVOURABLE ETHICAL OPINION

Study Title: The adaptive reuse potential of obsolete inner-city car parking structures for urban farming and local food supply: 3 UK case studies

Reference Number: CCIFEC 015- 2018 Monika Szopinska-Mularz

Date submitted: 9th August 2018

Version Number: Version 2

Thank you for resubmitting your application to the Faculty Ethics Committee.

As previously stated this is a very interesting and challenging piece of research. You have addressed the issues that we raised in the provisional opinion letter.

CCI Ethics Committee was content to grant a favourable ethical opinion we have added some conditions (generally grammatical and spelling requirements) of the above research on the basis described in the submitted documents listed at Annex A, and subject to standard general conditions (*See Annex B)*.

Conditions: please ensure that these are addressed before the commencement of the project for they relate to the material that will be distributed and issued to external particiupants and reflect the professionalism of the school of architecture and the university.

1. Please check the spellings in the invitation letter, **farming** not farmin and **length** not lenght. (we recognise that these sort of mistakes are easily made especially with predictive text corrections, nevertheless they should be checked).

2. Generally, please make sure that that the grammar is checked in all of the documents before they are distributed to external participants. Some sentences are not constructed sufficiently and some are not complete.
There are several examples and therefore it would be better that you check the documents with your supervisor. Following this one of the ethics committee members can provide a quick overview. It is very important for clarity and the professional quality of the documents.

3. The Participant Information sheet refers to 24 participants, the application states 20. Please adjust for correctness and consistency.

Please note that the favourable opinion of CCI Ethics Committee does not grant permission or approval to undertake the research. Management permission or approval must be obtained from any host organisation, including the University of Portsmouth or supervisor, prior to the start of the study.

Wishing you every success in your research

CCI Faculty Ethical Committee

Catherine Teeling

Catherine Teeling (Arch) – Chair CCI Ethic Committee

Annexe

A - Documents reviewed

Statement of compliance

CCI FEC is constituted in accordance with the University Ethics Policy.

Feedback

You are invited to give your view of the service that you have received from the Faculty Ethics Committee. If you wish to make your views known please contact the administrator at ethics-cci@port.ac.uk

<u>ANNEXE A</u> **Documents reviewed**

The documents ethically reviewed for this application

Document	*Version*	*Date*
Application Form	V2	08/08/2018
Invitation Letter	V2	08/8/2018
Participant Information Sheet	V2	08/08/2017
Consent Form	V2	08/08/2018
Participant profile	V2	08/08/2018
Survey Instrument	V2	08/08/2018
Interview questions (Topic List)	V2	08/08/2018

Risk Assessment Forms	V2	08/08/2018
Interview form for particpants	V2	08/08/2018

FORM UPR16

Research Ethics Review Checklist

Please include this completed form as an appendix to your thesis (see the Research Degrees Operational Handbook for more information

UNIVERSITY OF PORTSMOUTH

Postgraduate Research Student (PGRS) Information		Student ID:	UP832620
PGRS Name:	Monika Szopinska-Mularz		
Department:	Architecture	First Supervisor:	Dr Antonino Di Raimo
Start Date: (or progression date for Prof Doc students)	1st October 2016		
Study Mode and Route:	Part-time ☐ Full-time ☒	MPhil ☐ PhD ☒	MD ☐ Professional Doctorate ☐

Title of Thesis:	The adaptive reuse of inner-city car parking structures for innovative controlled environment agriculture systems. An architectural and urban investigation into the potential for the sustainable regeneration of modern derived infrastructures in some contemporary UK cities.
Thesis Word Count: (excluding ancillary data)	82 756

If you are unsure about any of the following, please contact the local representative on your Faculty Ethics Committee for advice. Please note that it is your responsibility to follow the University's Ethics Policy and any relevant University, academic or professional guidelines in the conduct of your study

Although the Ethics Committee may have given your study a favourable opinion, the final responsibility for the ethical conduct of this work lies with the researcher(s).

UKRIO Finished Research Checklist:
(If you would like to know more about the checklist, please see your Faculty or Departmental Ethics Committee rep or see the online version of the full checklist at: http://www.ukrio.org/what-we-do/code-of-practice-for-research/)

a) Have all of your research and findings been reported accurately, honestly and within a reasonable time frame?	YES ☒ NO ☐
b) Have all contributions to knowledge been acknowledged?	YES ☒ NO ☐
c) Have you complied with all agreements relating to intellectual property, publication and authorship?	YES ☒ NO ☐
d) Has your research data been retained in a secure and accessible form and will it remain so for the required duration?	YES ☒ NO ☐
e) Does your research comply with all legal, ethical, and contractual requirements?	YES ☒ NO ☐

Candidate Statement:	
I have considered the ethical dimensions of the above named research project, and have successfully obtained the necessary ethical approval(s)	
Ethical review number(s) from Faculty Ethics Committee (or from NRES/SCREC):	CCIFEC 015- 2018 Monika Szopinska-Mularz
If you have not submitted your work for ethical review, and/or you have answered 'No' to one or more of questions a) to e), please explain below why this is so:	
Signed (PGRS) : Monika Szopińska-Mularz	Date: 16 June 2020

UPR16 – April 2018

APPENDIX E Biography of the student

Monika Szopinska-Mularz is a PhD student at the University of Portsmouth in the Faculty of Creative and Cultural Industries. She was born in 1986 in Rzeszow, Poland. She graduated from Wroclaw University of Technology in 2010 with a Master of Architecture degree. During her studies, she spent one year as an Erasmus student at the Bauhaus University in Weimar, Germany. In 2009, during her senior year at university, she was awarded special selection praise in the *JAD International Design Competition* in South Korea for creating a *Soft Space* as a conceptual reaction to the recent worldwide economic crisis.

In October 2010, Monika took part in the Leonardo DaVinci (European Union-funded) programme, which allowed her to commence professional work as an architecture graduate in the practice of KuP Architekten in Frankfurt am Main, Germany.

From 2011 to 2015, she worked as an architect in ST Architekci, an office in Rzeszow, Poland. During this time, her work focused mainly on single and multi-family housing, health care buildings and green building design. In 2014, Monika passed the Polish Architect`s professional examination and registered as a Chartered Architect.

In October 2012, Monika started to work as an professorial assistant at the Rzeszow University of Technology, where she taught courses on hand drawing, regeneration of neglected urban areas, interior design and history of art and architecture.

As a PhD student at the University of Portsmouth, Monika was a postgraduate students` representative and a member of the Faculty Ethics Committee for the School of Architecture.

Professional memberships:

Monika is a registered member of Poland's Chamber of Architects. She is also a member of the Cluster for Sustainable Cities and Poland`s College of Swimming Referees.

List of publications

1. Szopińska, M., Prokopska, A. (2013). Areas from the past as a housing estate of tomorrow. *Housing Environment*, Cracow: Cracow University of Technology.

2. Szopińska-Mularz, M. (2014). Architectural contrasts in Seoul and pedestrian public space. *Housing Environment*, Cracow: Cracow University of Technology.

3. Szopińska-Mularz, M. (2015). The revitalization process and the strategy of the temporary revival of urban space on the example of Edinburgh. *ARCHITECTURAE et ARTIBUS*. Białystok: Białystok University of Technology.

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6. Szopińska-Mularz, M. A., & Lehmann, S. (2019). Urban farming in inner-city multi-storey car-parking structures: adaptive reuse potential. Future Cities and Environment, 5(1), [4]. https://doi.org/10.5334/fce.50